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Notices of the Aëronautical Society of Great Britain

GENERAL NOTICES

September Elections: *Associate Member:*—GEORGE BARKER.
Member:—LIEUT.-COL. R. DE VILLAMIL, R.E. (ret.).
Student:—JOHN JOHNSTON.

October Election: *Foreign Member:*—W. M. FANE-PENDLEBURY.

November Election: *Foreign Member:*—CAPT. H. E. VON SIMSON.

¶ **Committees.** The following Committee has been appointed by the Council:—

Finance Committee:—A. E. BERRIMAN, GRIFFITH BREWER, J. H. LEDEBOER, F. HANDLEY PAGE, and MAJOR-GENERAL R. M. RUCK (Chairman).

¶ **War Office Technical Reserve Committee.** The following letter has been received from the War Office by Colonel J. D. Fullerton (the Society's representative on the above Committee):—

"22nd November, 1912.

"SIR,

"I am commanded to inform you that in consequence of the progress which has been made in the organisation of the Royal Flying Corps the Army Council have decided to dissolve the Advisory Committee on Aeronautics (Technical Reserve).

"I am further to express the Council's high appreciation of the value of the services which you have been good enough to place at their disposal in connection with the work of the Committee.

"I am, Sir,

"Your obedient Servant,

(Signed) "E. W. D. WARD."

¶ **Wilbur Wright Memorial Fund.** The following subscriptions have been received :

	£	s.	d.
Amount previously acknowledged	500	0	0
F. H. Butler	10	10	0
Chas. E. Lamb (250 francs)	9	18	5
C. G. Grunhold	3	3	0
Dr. E. H. Hankin	3	3	0
Leeds University Engineering Society	1	10	0
Lieut. C. J. Randall, R.N.	1	1	0
J. Obermeyer	1	0	0
E. T. Sturdy	1	0	0
L. L. Vigers	1	0	0
Mrs. D. B. Warner	0	10	6
G. D. Barclay	0	5	0
Seymour Nation	0	5	0
	£533	5	11

Additional Joint Fund divided equally between the French Monument and Wilbur Wright Memorial Fund :—

	£	s.	d.
Griffith Brewer	10	10	0
Alec. Ogilvie	10	10	0
F. K. McClean	10	10	0
T. P. Searight	2	2	0
Mrs. Griffith Brewer	1	1	0
H. Massac Buist	1	1	0
Hon. Mrs. Assheton Harbord	1	1	0
Rt. Hon. The Lord Montagu of Beaulieu	1	1	0
Miss Betty Brewer	1	0	0
Master Cyril Brewer	1	0	0
Dr. William S. Lockyer	1	0	0
Eustace Short	1	0	0
Horace Short	1	0	0
Oswald Short	1	0	0
	£43	16	0
	533	5	11
Fifty per cent. of £43 16s.	21	18	0
Grand Total	£555	3	11

¶ **Programme for Winter Lectures.** The following meetings have been arranged for the forty-eighth session, and will take place at the Royal United Service Institution, Whitehall, at 8.30 p.m. :—

Wednesday, November 13th.—" Aeroplanes in the light of the Military Trials." By A. E. Berriman, A.F.Aë.S. General Sir Horace Smith-Dorrien, K.C.B., D.S.O., p.s.c., in the chair.

Wednesday, November 27th.—" Aircraft as Targets for Artillery and Rifle Practice." By Brigadier-General F. G. Stone, p.s.c., Officer commanding Royal Artillery S.W. Coast Defence, Southern Command. General Sir James Grierson, K.C.B., C.V.O., in the chair.

Wednesday, December 11th.—" The Mathematical Theory of Aeroplane Stability." By E. H. Harper, M.A. Dr. R. T. Glazebrook, F.R.S., in the chair.

Wednesday, January 15th.—"Stresses and Stress Diagrams relative to Aeroplane Structure." By F. Handley Page, A.F.Aë.S. Professor W. C. Unwin, F.R.S., in the chair.

Wednesday, January 29th.—"Stability Devices for Aeroplanes." By Mervyn O'Gorman, M.I.M.E., A.F.Aë.S. Brigadier-General D. Henderson, D.S.O., C.B., in the chair.

Wednesday, February 12th.—"The Law of Similarity Connecting Models and Full-sized Machines." By L. Bairstow, A.R.C.Sc. Sir William White, K.C.B., F.R.S., in the chair.

Wednesday, February 26th.—"Military Aviation." By Major F. H. Sykes, Royal Flying Corps.

Wednesday, March 12th.—"Some Research." By A. P. Thurston, B.Sc., A.F.Aë.S.

Wednesday, March 26th.—Annual General Meeting at 8.0, followed at 8.30 by "Hydro-Aeroplanes." By Commander C. R. Samson, R.N.

Wednesday, April 9th.—"Propellers." By W. O. Manning, A.F.Aë.S. Sir John Thornycroft, F.R.S., in the chair.

Wednesday, April 23rd.—"Aeroplane Construction." By Archibald R. Low, M.A. A.F.Aë.S.

Wednesday, May 7th.—"Atmospheric Waves, Eddies and Vortices." By Colonel H. E. Rawson, C.B., R.E. Dr. H. N. Dickson, D.Sc. (President, Royal Meteorological Society) in the chair.

Wednesday, May 21st.—Wilbur Wright Lecture.

1.—Discussions will take place after each Lecture.

2.—Members do not require tickets of admission and have the privilege, under the Rules, of introducing visitors to General Meetings.

3.—Tickets for visitors, not introduced, may be obtained of the Secretary, Aeronautical Society of Great Britain, 11, Adam Street, Adelphi, W.C.

4.—Extra Lectures and details, and changes in the dates of Lectures are advertised in *Flight*, *The Aeroplane*, *Aeronautics*, and *The Car*.

¶ **Library.** The Council begs to thank the following gentlemen for their gifts to the Library :—Mr. C. Dendy Marshall, M.A., for a copy of *Experiments in Flying Machines*, by the late Percy S. Pilcher. Mr. J. Hume-Rothery for a copy of his paper on *One Explanation of the Soaring of Birds*. Mr. Mervyn O'Gorman for a copy of *Airships and Aeroplanes*. Captain H. F. Wood for the gift of 42 lantern slides.

¶ **Aero Show, 1913.** The International Aero Show will open at Olympia on February 14th, 1913, and terminate on February 22nd. The number of the Society's stand will be announced later.

¶ **Loan Exhibition, Science Museum, 1912-13.** A temporary collection illustrating the development of Aeronautics is now being got together at the Science Museum. The Exhibition will last about six weeks in December and January. The Society is contributing many portraits and prints, Stringfellow's model aeroplane and light-weight steam engine, the Pilcher Glider from which Pilcher met his death, and a Lilienthal Glider.

Members possessing relics of early pioneers are requested to communicate with the Secretary at 11, Adam Street, Adelphi.

GENERAL MEETING

THE SEVENTH MEETING of the Forty-Seventh Session of the Aëronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S.W., on 16th May, 1912, at 8.30 p.m. The chair was occupied by Mr. F. Grant Ogilvie, C.B., Director of the Science Museum.

AERONAUTICAL RESEARCH AT THE NATIONAL PHYSICAL LABORATORY

BY FRANCIS H. BRAMWELL, A.C.G.I., B.SC.(LOND.), D.I.C., A.F.AË.S.

MR. CHAIRMAN AND GENTLEMEN,—Before proceeding with the subject of this lecture I wish to make a short explanation.

I am only able to deal with the experimental work carried out at the National Physical Laboratory up to March, 1911, that is, with the results so far published by the Advisory Committee for Aeronautics. The results of the work done during the last year, very largely dealing with aeroplane problems, will probably not be published until next month or the month after.

I propose to divide my subject into several sections and to describe the apparatus used under each separate section.

Turning first to the work that has been done on the resistance and stability of dirigibles, I will merely touch on the stability results, as not bearing so directly on the problem of the aeroplane as the resistance results; which are interesting owing to the increasing use of covered-in bodies for aeroplanes.

These tests were carried out in a small water channel, 12 ins. wide and 7 ins. deep, the range of speed being from 1·0 to 1·9 feet per second, within which range the resistance was practically proportional to the square of the speed.

All the results have been reduced to a speed of 1·78 feet per second.

The models (the maximum diameter of which was 1 in. in all cases) were hung from a knife edge by a vertical spindle, the weighing lever being horizontal, *i.e.* at right angles to the supporting spindle, so that the resistance of the model was measured directly by weights on this lever.

The velocity of the water in the channel was measured by a sensitive tilting gauge (mercury was used in the gauge for these experiments in water), connected to a Pitot tube and a static pressure tube in the channel.

The resistance of the models was expressed in terms of the total lifting capacity of the gas, *i.e.* in terms of the volume of the model.

On this comparison the finer models were found to be much superior to the blunter ones.

Some further experiments were then made on the effect of increasing the length of a model by introducing parallel sections of various lengths between the heads and tails of the various models.

In all cases the increase in resistance was proportional to the increase in length, the increase being due to skin friction.

So that the law connecting resistance with volume for any particular model is

$$R = a + bV$$

The term " a " being independent of the volume is a measure of the efficiency of the head and tail.

The most efficient was found to be with a fine head and tail. Not only was the blunt tail found to be very inefficient, but also the blunt head.

In all cases the lifting capacity for a given resistance increased with increase in length, the limiting value being the same in all cases for a balloon of infinite length; as then the effect of the differences in head and tail resistance was negligible.

The resistances measured were probably all high, due to some effect of shallow immersion, as it was found that a reduction in the height of the water above the model of $\frac{1}{2}$ in. increased the resistance by about 10 per cent.

The general conclusion drawn from the work is that a length of head of $1\frac{1}{2}$ diameters and a length of tail of at least 3 diameters are required for a reasonably small resistance.

The importance of the use of a covered-in body for an aeroplane may be gathered from the following rather startling figures.

The resistance of a covered body of the shape of some of the best balloon models tested at the National Physical Laboratory would only be 13 lbs. at 40 miles per hour, for a body 6 feet in diameter and 36 feet long.

This is a body sufficiently large for a man to walk about inside.

The resistance of the exposed parts (apart from the lifting planes) in a modern machine is of the order of 100—150 lbs. at 40 miles per hour, so that the extreme importance of this matter is shown up very clearly.

Some work was also done on the resistance of balloonettes and fins; but this has no direct bearing on aeroplane problems.

Any elongated body, such as a dirigible without fins, will, when slightly inclined to either side of its direction of motion, tend to turn broadside on to such direction.

Experiments were made to determine the lift, drift and the position of the resultant force on balloon models at various inclinations of the axis to the stream. The lift and drift were measured on the balance previously described; this determines the resultant force in magnitude and direction, but not in position.

The position, or point of application, of the resultant force was determined by pivoting the model at various points along its axis; and measuring the inclination which it took up relative to the stream for each particular position of the pivots.

The moments acting on the model at various inclinations can be deduced from these measurements, but a separate apparatus was designed for this purpose.

The model was held on a vertical spindle, which was pivoted so that it was free to rotate; the rotation being controlled by two springs acting on a lever arm. The amount of rotation was measured by observing the reflected image of a scale in a telescope, the reflecting mirror being carried on the vertical spindle.

The whole apparatus, including the model, can be rotated to various inclinations. A zero having been taken, on the reflected image of the scale in the telescope, with the stream stopped, the stream is set running and the deflection of the image of the scale in the telescope is proportional to the moment acting on the model for the new inclination to the stream.

It was found that even with a fine tailed model, narrow fins placed close to the tail had very little stabilising effect, showing that they were in a stream of low velocity.

This was further brought out in Mr. Eden's visual experiments.

His apparatus consisted of a small water channel 3 ins. wide, 4 ins. deep and about 10 feet long, with glass sides; the maximum velocity being about 2 inches per second. A cloud of coloured fluid was allowed to flow past the model and was seen to remain in the region of sluggish flow for some time.

It was found that the diameter of the dead water or sluggish flow region was very much greater for blunt tailed models than for those with fine tails.

The diameter of the dead water region was found to increase with the velocity; this was measured for one of the blunt tailed models for a range of speed from 0·1 feet per second to 2·3 feet per second, the increase in diameter being from 40 to 82 per cent. of the diameter of the model.

As the velocity at which these tests were carried out corresponds to a very low velocity for the full size balloon it is probable that even a fine tailed balloon will have a considerable dead water or sluggish flow region at normal speeds.

These stability experiments show the extreme importance of providing adequate stabilising fins with a covered-in aeroplane body. Of course the rudder may be utilised for this purpose, or *vice versa* the stabilising fins may be used as a rudder.

I now come to the tests that have been made on various rudders and lifting planes.

Some preliminary tests on combinations of rudders were made in the small water channel, which has been already described.

[The curves which were here shown, of normal pressure—in lbs. per sq. foot for a current of air of 30 miles per hour—plotted against angles from 0° to 90°, were calculated directly from the measured normal forces in the water channel.]

The tests showed that the double and triple rudders soon fell off in efficiency (compared with a single rudder) as the angle was increased.

Further tests were then made in a 4-foot square horizontal channel on the suction side of a 6-foot belt driven Sirocco fan, the air returning through an outer channel 8 feet square.

The velocity in the channel is measured by means of a Pitot and static pressure tube, connected to opposite limbs of a sensitive tilting water gauge, the static pressure in this case being measured by the pressure in a small hole in a flat plate let into the side of the channel.

Three combinations of lifting planes were tested for lift and drift, at various inclinations to the current.

The area and size of the planes were the same in all cases, each set consisting of four parallel planes.

The planes of Set No. 1 were similar to an aeroplane in section; those of Set No. 2 were fish-form in section; while those of Set No. 3 were also fish-form in section, but the front portion was fixed in direction and only the tail portion was put at different inclinations to the current.

It was found that Set No. 1 was by far the most efficient at positive inclinations; the lift and also the ratio, lift over drift, being considerably higher at say $+30°$ inclination than either of the other sets.

At negative inclinations the ratio of lift to drift was greatest for Set No. 3.

These three sets are interesting as illustrating the three types of tail that are in use at the present time.

No. 1 is an example of the ordinary lifting tail, No. 2 of the ordinary neutral tail, while No. 3 is analogous to the flexible tail plane that has been tried on some machines.

The position of the centre of pressure of a rudder of fish-form section was determined for various inclinations to the air current.

The rudder was pivoted at various points along its axis, and the inclination it assumed relative to the air current was measured to an accuracy of about $1°$ by means of an inclined mirror reflecting a graduated dial on the roof of the channel.

It was found necessary to use an oil dashpot to damp out the oscillations in order to get a steady reading.

The experimentally determined curve was plotted, and also the theoretical distance of the centre of pressure from the leading edge of a thin plate

$$x = \left(\tfrac{1}{2} - \frac{3 \cos \alpha}{4\ (4 + \pi \sin \alpha)} \right) l$$

where α is the inclination of the plate to the stream and l is its length down stream.

It was found that the experimentally determined positions were all appreciably ahead of the theoretical positions for a thin plate.

For the plane parallel to the stream, the distance of the centre of pressure from the leading edge was found to be $\frac{l}{4}$ instead of $\frac{5l}{16}$, as given by the formula.

This value is important as showing how far from the leading edge rudders, &c., should be pivoted, so that in case of the controlling wires breaking, they should set themselves in a neutral position.

A rather interesting series of tests was made on a model of the girder designed by Fabre and used on the Paulhan aeroplane.

The lift and drift were measured for various inclinations (A) about an axis parallel to the length of the girder and (B) about a vertical axis.

In the first case the maximum value of the ratio of lift to drift occurred at an inclination of $7°$ and was approximately 5. In the second case the lift was negligible.

I understand that the only reason for the discontinuance of the use of this form of girder was the failure of a satisfactory agreement between the designer and the manufacturer.

Some series of tests were made on a model radiator of the honeycomb type, from which it was found that the wind resistance of this type, with a net area of about 25 per cent.

of the total, was about 50 per cent. of that of a flat board of the same dimensions. Also this type was fairly efficient as a radiator, and it did not appear that any considerable increase of efficiency could be obtained by increasing the pitch of the tubes or by shortening them.

[Mr. Bramwell referred briefly to the first series of motors tested for the Alexander Motor Prize Competition. This was very fully discussed at the time in the Aeronautical Press, and the apparatus, being only indirectly aeronautical, need not be described here.]

For propeller testing at the National Physical Laboratory we have a whirling arm of 30 feet radius in a closed room 80 feet square.

Only model propellers are tested, generally 2 feet in diameter.

The centre of the propeller is 6 feet from the floor and 10 feet from the walls, so that the air flow from the propeller may be free from interference.

The whirling arm is driven by a 12 H.P. motor through a worm gear at the centre of the arm, the propeller being separately driven by a 2 H.P. motor mounted on the arm and capable of running up to a speed of 3600 revolutions per minute.

The propeller tests described in the Report of the Advisory Committee were carried out on the old propeller dynamometer.

This was designed primarily for powers up to $\frac{1}{2}$ H.P. and speeds up to 1800 revolutions per minute, so that it was considerably overloaded in these tests.

In this dynamometer, the propeller was mounted about 2 feet behind the arm.

The propeller shaft bearings were mounted on swinging links, so that the shaft was free to move along its axis, being controlled by a calibrated spring at the lower end of one of the swinging links. The thrust required was set beforehand by screwing up this spring to any required tension.

The arm was then run up to any translational speed desired by means of the centre motor. The propeller speed was then run up till the thrust of the propeller just balanced the pull in the spring.

This caused the propeller shaft to move forward a small amount, moving the lower end of the swinging link on to a contract, connected to a telephone on the observing table, where it gave a signal.

The drive between the belt pulley and the propeller shaft was through a coiled spring. The belt pulley carried a drum on which was a piece of metallic paper, and the propeller shaft carried a metal point pressing on this paper, so that the movement of the point over the paper measured the torque on the propeller. The point made a mark on the paper while the speed of the propeller was being increased; but when the pull of the spring was balanced and the propeller shaft moved forward it caused the point to move sideways across the drum, so that the torque corresponding to the thrust could be measured.

The speed at the same instant was observed by the voltage of a small dynamo driven from the end of the propeller shaft. The speed of the arm was measured by timing its revolutions against a stop watch.

A second arm of light construction was built out opposite to the existing arm and carries a Pitot tube at the end. This is for the purpose of measuring the rotation of the air in the building, set up by the rotation of the arm.

The pressure in the mouth of the Pitot tube is half the density of the air multiplied by the square of its velocity through the air, above the atmospheric pressure.

But, owing to the centrifugal force on the air in the tube connecting the Pitot tube to the centre of the arm, the pressure in the mouth of the Pitot tube must be half the density of the air multiplied by the square of its velocity relative to the ground, above the pressure in the connecting tube at the centre of the arm.

If these two velocities are not the same, the pressure in the connecting pipe at the centre of the arm differs from the atmospheric pressure; and this difference in pressure taken in conjunction with the speed of the arm is a measure of the speed of the air round the room, *i.e.* of the difference between the speeds of the Pitot tube relative to the ground and to the air in the room. For

$$h = \tfrac{1}{2}\rho(V^2 - v^2)$$

Where h is the difference in pressure,
ρ is the density of the air,
V is the velocity of the Pitot tube relative to the ground,
v is the velocity of the Pitot tube relative to the air,
and (V—v) is the velocity of the air flow round the room.

The chief advantage of this method is that it measures the difference of squares of two nearly equal quantities, which is very much bigger than the difference between the quantities.

[Some results of tests on Ratmanoff model propellers (2 feet in diameter) were shown by means of slides.]

A preliminary series of tests to determine the effect of reducing the blade width was made on a model propeller, 2 feet in diameter, made by Messrs. Vickers Ltd.

The various propellers of the series were cut down from the one propeller; they were all tested at a thrust of 2·05 lbs. and a translational speed of 14·6 miles per hour.

Under these conditions it was found that a blade width of about 5 inches was the most efficient.

One of the blade shapes was made an exact model of a full-size propeller, 15 feet in diameter, that had been tested on the whirling arm at Barrow.

The determined values agreed very closely indeed with the values predicted from the tests on the full-size propeller.

These predictions were made on what are known as the square law assumptions, *i.e.*, for two similar propellers, running at the same slip ratio; the thrusts are in the ratio of the fourth powers of the linear dimensions and the squares of the rotational speeds; the torques are in the ratio of the fifth powers of the linear dimensions, and the squares of the rotational speeds, so that the efficiencies are the same in the two cases.

In the last few months the central framework has been stiffened up considerably, and a more powerful dynamometer has been installed. This is arranged so that the propeller is in front of the arm, and in general principle is identical with the older one.

The slight axial motion of the propeller shaft is obtained by mounting it in special ball bearings with cylindrical outer races, the torque springs have been made considerably stiffer, and the pencil gear for registering the torque has been abandoned. The registration is now done by sparking through the paper on the drum when the pull of the propeller just balances the pull of the thrust spring; this is under the control of the observer and is very satisfactory.

The oscillations of the torque springs are damped out by a dashpot consisting of flat discs immersed in oil with small clearances; there is no dashpot to damp out oscillations of the thrust spring as it has not been found necessary.

The small dynamo is kept as an indication of the speed, but a direct counter is now used for measuring the propeller speed.

Every revolution of the whirling arm and every hundred revolutions of the propeller shaft move two pens on a moving strip of paper, by making electrical contacts; the pens being worked by means of electromagnets. A third pen registers seconds from a standard clock. By this means the speeds are determined to about $\frac{1}{5}$ per cent., the dynamometer otherwise being sensitive to about $\frac{1}{2}$ per cent.

There is one other fitting that is worthy of mention. The propeller shaft is mounted so that the plane of the propeller passes through the centre of the whirling arm, the propeller shaft being thus at right angles to the radius of the whirling arm at the centre of the propeller; and the centrifugal force on the propeller, due to the rotation of the arm, has no component along the propeller shaft. But, at its mass centre, the propeller shaft is not at right angles to the radius of the whirling arm, so that the centrifugal force on the propeller shaft, due to the rotation of the whirling arm, has a small component along the propeller shaft.

This is balanced by a small bob-weight, also acted on by centrifugal force due to the rotation of the arm, which presses against the swinging link to which the thrust spring is attached, so that this component is balanced at all speeds.

I now come to some very interesting results in view of the paper on the laws of similarity that is to be read during next session.

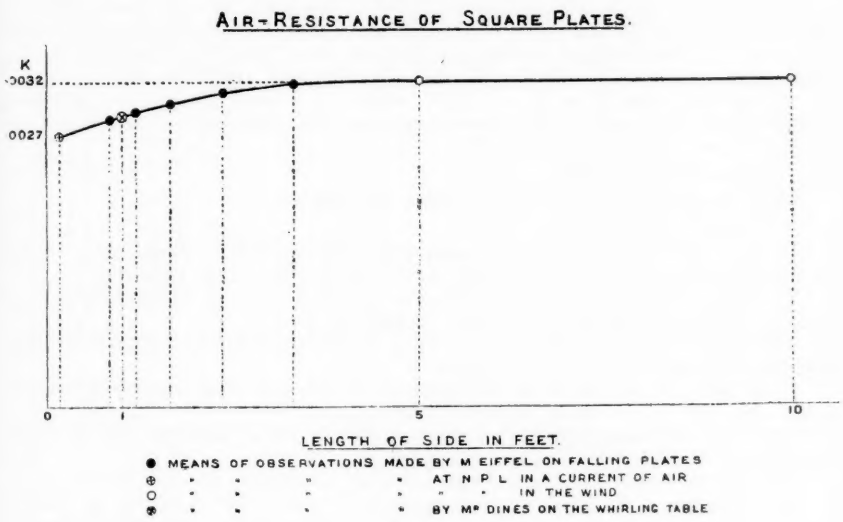


FIG. 1.

Fig. 1 shows the values of K for the normal pressure on square plates plotted against the length of the side of the plate in feet.

The total normal force on the plate is

$$F = c\rho l^2 v^2.$$

Where ρ is the density of the air (mass per unit volume), l the linear dimensions of the plate, and v the air speed.

So that the mean pressure per sq. foot is

$P = Kv^2$ (l in feet and v in miles per hour).

These observations are from various sources, the smallest plate being tested in a small vertical wind channel at the N.P.L. The two largest plates were tested in a natural wind, on a wind tower at the N.P.L. One plate was tested by Dines on a whirling arm and the others are Eiffel's determinations on falling plates.

It will be noticed that the value of K increases with the size of the plate, and that the values are very consistent among themselves. But Lord Rayleigh has shown theoretically, from the principle of dynamical similarity, that the total force on a square plate must be

$$F = \rho l^2 v^2 \Phi\left(\frac{vl}{\gamma}\right)$$

$$\text{so that } P = v^2 f\left(\frac{l}{\gamma}\right)$$

or else both C and K must be constants.

This is on the assumption that the speed is so low that the effect of the elasticity of the air may be neglected.

γ is the kinematic coefficient of viscosity of the air.

In other words if the value of K varies with the size of the plate, it must also vary with the velocity (γ being constant); so that the pressure on a given plate cannot be strictly proportional to the square of the speed.

In Fig. 2 the values of K have been plotted against the values of the product vl for the various plates, and they are found to be very well on a straight line.

The 5-foot square board tested at the N.P.L. is known to be open to considerable error, as there was some uncertainty with regard to the zero of pressure in the observations on this board. Also subsequent experiments have shown that the value obtained by Dines is uncertain, owing to its having been determined on a whirling arm.

So that by writing K as $K^1(1+a(vl))$; where a is a small number and K^1 is a constant, both the experimental observations and the theoretical equation can be satisfied.

Then $F=A(l^2v^2)+B(l^3v^3)$

where A and B are constants, if ρ and γ are constant.

B is a small number.

In Fig. 3 curves of this form are shown drawn through Eiffel's observations. They are seen to fit the points very well, quite as well as, or better than, parabolas.

The theoretical consideration therefore does not clash with the experimental results, which is all that is required to establish a theoretical law.

This theoretical consideration of the subject has been justified by a number of other experiments, such as the friction in pipes.

I now come to some results on the resistance of wires and ropes, which were treated in the same way as the results from the square plates.

These were obtained in a small vertical channel, 2 feet in diameter, the air being sucked down by a propeller fan and exhausted into the room.

The balance was of an ordinary type and does not require any description.

The diameters of the ropes were measured by winding 20 turns of very fine cotton on to each rope and dividing the length by 20 π. This method gave very consistent values for the mean diameters.

From similar considerations to those just given for square plates, the resistances per diameter length of the smooth wires were plotted against the square of the product of the velocity and the diameter.

The curve obtained is shown in Fig. 4 in three sections.

It will be noticed that all the points lie well on the curve, which approximates to a straight line.

It should be pointed out here that this curve is a sufficiently good approximation to a straight line for the resistance of wires to be taken as proportional to the square of the speed and to the projected area facing the wind in all practical problems.

The necessity of allowing for the departure from the square law is only of vital importance in the question of the use of models, in which results on a full-size machine have to be predicted from a very small scale model.

The force R on a length of wire l of diameter D at a speed v in air is

$R=KDlv^2$, where K is a function of (vD); as in air both ρ and γ are constant.

The same signs as in Fig. 4 are used for the different wires.

The values of this coefficient K are plotted against the product (vD) in Fig. 5, from which it is seen that it has a considerable variation.

The hemp and stranded steel ropes cannot be plotted in the same way, as the theoretical investigation presupposes that the ropes are all geometrically similar in all respects.

The mean values of K in foot-pound-second units are :—

0·00107 for the smooth wires
0·00129 for the stranded wires and ropes.

These agree very well with some values obtained at Göttingen, the values obtained there being 0·00108 for smooth wires
and 0·00128 to 0·00144 for ropes.

There is a very universally held opinion that the resistance of a vibrating wire is considerably higher than that of a stationary one.

The resistance was determined at the N.P.L. of a wire 16 ins. long and 0·063 ins. diameter, held at the centre.

The whole balance was made to vibrate by means of a small motor with an unbalanced pulley.

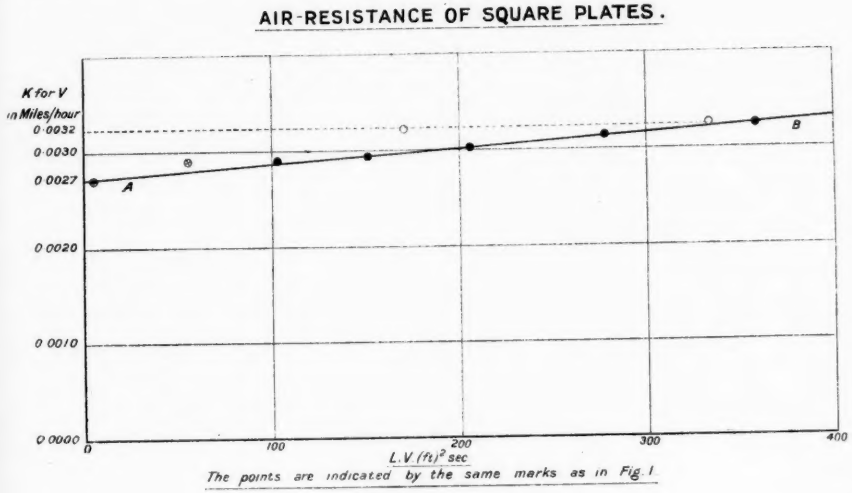

AIR-RESISTANCE OF SQUARE PLATES.
K for V in Miles/hour
0·0032
0·0030
0·0027
0·0020
0·0010
0·0000
A
B
0
100
200
300
400
L.V (ft)² sec
The points are indicated by the same marks as in Fig. 1

FIG. 2.

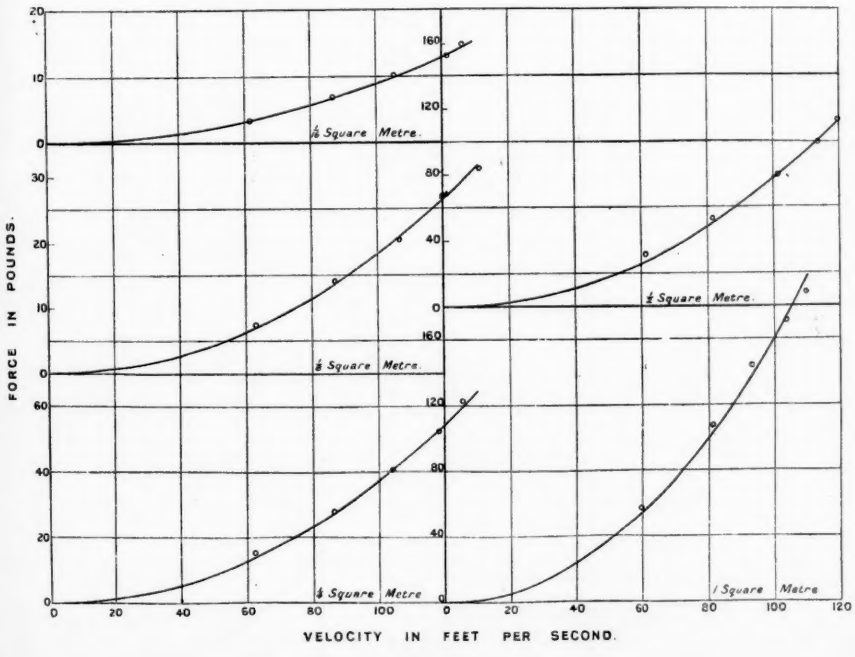

AIR RESISTANCE OF SQUARE PLATES.
FORCE IN POUNDS.
¼ Square Metre.
⅛ Square Metre.
1/16 Square Metre.
1 Square Metre.
VELOCITY IN FEET PER SECOND.

FIG. 3.

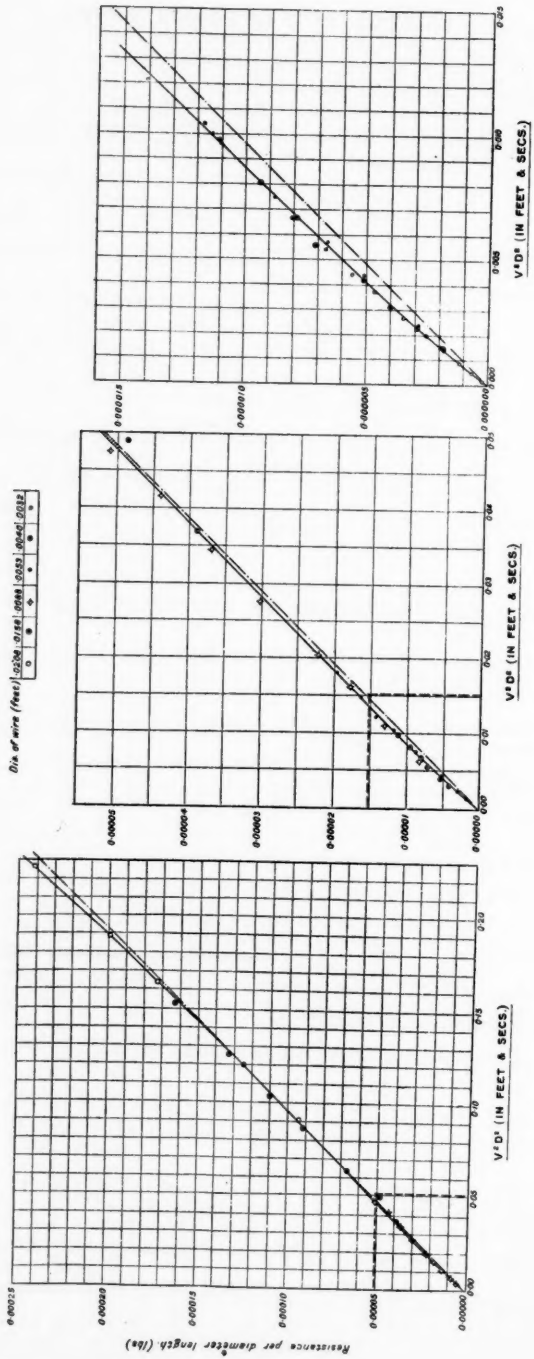

Resistance per diameter length (lbs.)
V²D² (IN FEET & SECS.)
Dia. of wire (feet)

FIG. 4.

By altering the speed of the motor until it synchronised with the natural period of vibration of the wire, it was possible to obtain an oscillation of more than $\frac{1}{2}$ inch amplitude at the end of the wire.

Although the resistance was very small the balance was sensitive to variations of about 3 per cent. of the total resistance or one twenty-thousandth of a pound.

It was found that there was no measurable increase of resistance with the wire vibrating either across or up and down the wind.

The speed of the motor was about 1300 revolutions per minute, and the speed of the wind was from 15 to 17 feet per second.

I have necessarily only touched on many points that may be of particular interest to individual members, as it is impossible to go into all details in the compass of one short lecture.

I shall be very pleased to give any information in my power on further points that may be raised by members.

RESISTANCE OF SMOOTH WIRES.

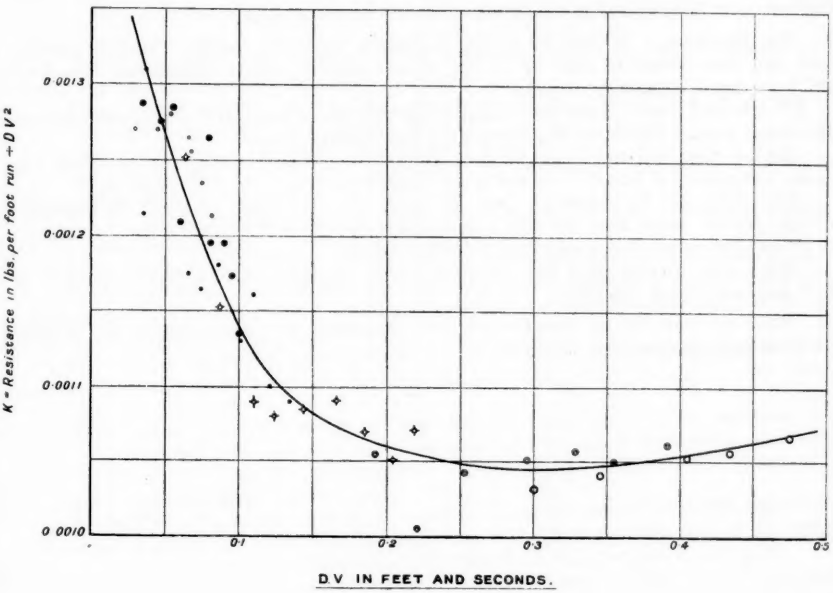


FIG. 5.

DISCUSSION

MR. HANDLEY PAGE asked whether the effect of placing obstructions before or behind propellers had been investigated—he thought such experiments would have great value.

MR. BERTRAM G. COOPER directed attention to the similarity of Prof. Graham Bell's tetrahedral cell sustainers to the Fabre girder used by Paulhan. The fact that the maximum lift/drift ratio of the latter was 5 only seemed to promise a low efficiency for the Bell sustainer.

He asked whether any attempt had been made to apply the law of similarity to determining the relative efficiencies of birds, insects and aeroplanes. Absurd claims had been made in some quarters as to the superior efficiency of the latter. As, however,

in the case of water transit, which was the most economical of power of any of the ways of getting about, we had certainly not approached anywhere near the efficiency of the whale or porpoise (power for power) it hardly seemed likely to him that, in the case of air transit, the least economical of power, we had done any better. He was anxious to obtain data bearing on this subject.

He said that, while it was most interesting to see how well the plottings came out in Fig. 2, it would be more satisfactory when the plate tests differed only as regards size of plate. In the case of Dines's experiments, for example, the centrifugal action of the air, due to their having been made on a whirling arm, introduced a factor which vitiated the results. He asked how far the same action had been found to affect the propeller tests at the N.P.L.

Mr. Archibald R. Low regretted that the ban of secrecy in regard to tests could not be relaxed in the case of some designers who could be trusted not to abuse any confidence placed in them. As it was, publication of the results of tests at the N.P.L. was often delayed till similar results had been obtained elsewhere.

Mr. A. E. Berriman said he was impressed by the careful manner in which incidental difficulties of experiment had been overcome. He asked whether the law of skin friction had yet been determined as exactly as that of normal pressure.

Mr. Bramwell, in replying to the discussion, said that, so far, ordinary propeller tests had been found to take up all the time available, and no interference tests had yet been made, although of value.

He excused himself from discussing further the law of similarity, preferring that such discussion should follow on Mr. Bairstow's forthcoming paper.

He said that the centrifugal air flow had not been found to affect the propeller tests to any very marked extent. It was most evident when working with high slip.

He could not, he regretted, give Mr. Low any "advance results," as practically all the N.P.L. tests were for the Government Advisory Committee for Aeronautics, at whose discretion only could results be published.

While skin friction tests had not been extensively gone into, it was found that the $V^{1.85}$ law gave good results.

After the concluding remarks of the Chairman, who was unanimously thanked for presiding, the meeting terminated.

THE FIRST MEETING of the Forty-eighth Session of the Aeronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S.W., on Wednesday, 13th November, 1912, at 8.30 p.m. General Sir Horace Smith-Dorrien, K.C.B., D.S.O., p.s.c., presided.

DISCUSSION

AEROPLANES IN THE LIGHT OF THE MILITARY TRIALS

OPENED BY A. E. BERRIMAN, A.F.AË.S.

Picture an imaginary aeroplane of constant power output having wings that grow smaller as the speed increases, and suppose that the change of area with speed is such that the loading in lbs. per square foot of wing surface is always given by the expression $V^2 \div 900$, where V is the speed in miles per hour.

Let it further be supposed in respect to this imaginary aeroplane that it grows lighter as it flies faster, and let the weight vary inversely as the speed.

Thirdly, let it be supposed that the resistance to motion is always one-sixth of the instantaneous weight of the machine at all speeds.

Finally, let it be supposed that the propeller has 80 per cent. efficiency at all speeds.

Let a graph be drawn to illustrate $V^2 \div 900$.

Let another graph be drawn to illustrate $1{,}800 \div V$.

Let both graphs be drawn on one chart with ordinates of miles per hour velocity and abscissæ of pounds weight.

Let the scale of the abscissæ marked on one side of the graph be called weight per h.p., while that opposite is called lbs. per square foot.

Such a chart will illustrate the case of the hypothetical aeroplane defined above.

Such a machine cannot actually exist, but a real aeroplane might, individually, represent one of its instantaneous conditions, and a series of aeroplanes might, collectively, cover a considerable range of its chart.

For this reason, I think it is interesting as a line of thought, although not necessarily useful for practical purposes, to compare the machines in the Military Trials with the chart.

Thus, for any given machine, we may take its weight per h.p. as an index to the chart and compare the actual wing loading and actual speed with those indicated as appropriate to the hypothetical condition. Alternatively, we may take the actual wing loading or the actual speed as the index and do likewise.

From this comparison, it may be possible to gain some idea of the effect of an alteration in either the weight or the wing area of a given machine, and if the chart in any way facilitates such an estimate, it might serve a useful purpose in doing so.

For the sake of being as definite as possible in the attempt to deal with this comparison verbally instead of merely placing the data graphically on the chart and leaving the conclusions to be drawn as others may see fit, I have supposed, purely for the sake of argument, that such a comparison is permissible.

This, it seems to me, is the most certain way of enabling others to judge for themselves whether or no it has any interest or value.

Criticism will thus fall under three heads :—

(*a*) That the graph is incorrectly drawn to represent the hypothetical case.

(*b*) That the data of the Military Trials show the hypothetical case to be useless.

(*c*) Or that, showing it conceivably to have some use, the deductions at present drawn are incorrect.

It will be understood that the hypothesis states interdependent conditions. Any alteration in one condition of necessity involves alteration in other conditions otherwise the hypothesis would be stating an absurdity.

Thus, no machine can move faster unless its power increases or its resistance decreases. In the hypothesis, the power is assumed constant in order to meet the case of a given engine employed on a variety of machines intended to fly at different speeds while carrying different loads. Under the hypothesis of constant power and increasing speed, therefore, the resistance *must* decrease with the speed.

In one and the same machine, such a decrease is obviously limited by the weight being constant. But a series of different machines (which is what the hypothesis is really intended to cover) might usefully carry different loads per unit of power, which would meet the conditions of the chart over a wider range.

The coefficient of resistance in terms of the weight is assumed to remain constant, because in an elementary aerofoil the coefficient of resistance is independent of velocity, provided that the angle remains unchanged while the area adjusts itself to the V^2 law and the weight, and that skin friction is $\propto V^2$.

If the area is not properly adjusted to the speed in accordance with the hypothesis, it will involve a reduction in the coefficient of resistance assumed in the hypothesis. Thus, if the area becomes too small, the weight per h.p. must be less, or the resistance coefficient must be less, or the appropriate wing-speed will not be attained. Alternatively, if the wings remain too large, the total lift will increase with speed, which again involves either a reduction of the resistance coefficient or an increase in the power.

It is not suggested that an actual aeroplane cannot demonstrate a departure from the assumed *numerical* values of the chart, but it is inferred that no machine can violate the primary *laws* on which the chart is based, and it is suggested, therefore, that such a chart facilitates an appreciation of the significant distinctions between the performances of different machines.

When the result of comparing proposed data with the chart is an indication that the power apparently required is different from the stated value, the former may be expressed as a percentage of the latter. I call the power apparently required, to fly the stated weight at the speed that the chart indicates, as appropriate to the stated loading by the symbol ϵ, which expresses the value as a percentage of the power stated to be available. If ϵ exceeds the value 80 per cent., which serves as the basis of the particular chart illustrated, then ϵ may be regarded as the "efficiency" anticipated.

The improvement necessary to satisfy the conditions, however, may be assumed to be located in the actual propeller efficiency or in the resistance coefficient; but some real improvement must have been accomplished in one or the other, or both, for the machine to satisfy the conditions.

Incidentally, it is of interest to note from the particular chart given that the product of weight per h.p. and weight per square foot (both in lbs.) is everywhere twice the flight speed in miles per hour. The product of the two terms I call X; thus $kX = V$ where k is a constant for any given chart. For the particular chart given, $k = \cdot 5$, but it may have any value compatible with the basis on which it is desired to establish a comparison.

Desiring to establish a basis of comparison near, but still within, the limits of modern attainment, I have analysed the actual flight speeds attained in the Military Trials by the aid of X, and therefrom have deduced that $k = \cdot 5$ would provide the desired basis. It is important to bear in mind, therefore, that X is an effect produced by the hypothesis and not the cause thereof. Also, that the constant k merely determines the scale for any particular chart.

1. With this explanation I now turn to the detail text of my paper, which first shows the origin of the numerical values assumed for the hypothetical case.

2. The Military Trials cost about £14,000, and these figures, therefore, cost several pounds apiece to collect; they should need no further introduction to ensure your interest.

3. The aspect of the aeroplane on which I shall try to throw the light of the Military Trials is that concerned with a relationship between wing area, weight and power.

4. Weight involves resistance. Power overcoming resistance involves speed. Resistance and speed equated to power involve efficiency.

5. Now let me analyse the figures in the table, so as to provide data for the subsequent synthesis.

6. If I multiply the gliding resistance of an aeroplane by its maximum flight speed, I get the figures under "T.V. max." in the table.

7. If I establish a ratio between T.V. max. and the known H.P. of the engine, I get figures of efficiency that, at least, were actually attained. These values appear under E_1 in the table.

8. The best E_1 is about 80 per cent.

9. If I divide the weight in flight by the power, I get the weight per h.p. (W_1).

10. Variation in W_1 is small, most machines carried about 24 lbs. per h.p.

11. The gliding angle is shown in the table under G.

12. Most machines achieved a gliding angle of at least 1 in 6.

13. Most machines, therefore, experienced a gliding resistance of about 4 lbs. per h.p.

14. Divide 80 per cent. of 1 h.p. by 4 lbs. and the result is a speed of 75 m.p.h.

15. All machines carrying 24 lbs. per h.p. should, therefore, have achieved 75 m.p.h. flight speed if they were of equally low resistance in design, and if the effect of wing loading is ignored.

16. Look at the wing loadings in the table, they vary much more than do the weights per h.p.

17. Let us compare four machines at random having nearly the same weight per h.p. Thus :—

Hanriot 1	6·4 lbs. per sq. ft. wing loading.
Blériot sociable	4·8 ,, ,, ,,
Bristol 14	8·75 ,, ,, ,,
Cody	5·55 ,, ,, ,,

18. Generally speaking, the reason for using larger wings is in order that a machine may *be able* to fly more slowly than before.

19. It would appear, therefore, that the above machines are *intended* to have different normal speeds, as they have widely different wing loadings.

20. Presumably all the intended speeds are below the limiting value of 75 m.p.h., which corresponds to the 24 lbs. per h.p. for the maximum demonstrated $E_1 = 80$ per cent., but, it will be interesting to enquire whether the designer of the machine with the highest loading may not have *anticipated* flying at a higher speed than this.

21. If he did so, then clearly he also anticipated realising a lower resistance than usual, or a higher transmission and propeller efficiency than usual.

22. If E_1 represents the transmission and propeller efficiency *actually* demonstrated, then let us call the efficiency anticipated when the resistance is assumed to be one-sixth of the weight ϵ.

23. It has been shown that E_1 has a maximum value in the order of 80 per cent. If, therefore, the value of ϵ appreciably exceeds this, it is clear that the designer expects to attain a better overall combination of high-propeller efficiency with low body resistance at high speeds than was achieved by any machine in the Military Trials.

24. In the absence of exact information, I suggest the following method of roughly estimating *a* speed that is appropriate to the wings, having regard to the load per h.p.

25. W_1 (wt./h.p.) is proportional to V^{-1}.
W_2 (wt./sq. ft.) ,, ,, V^2.
W_1W_2 is, therefore, proportional to V.
I call W_1W_2 by the symbol X.

26. In X, I have therefore a term in some way related to the speed that is appropriate to a machine having the stated W_1 and W_2 ; and we may write $kX = x$ where x is the appropriate speed in miles per hour.

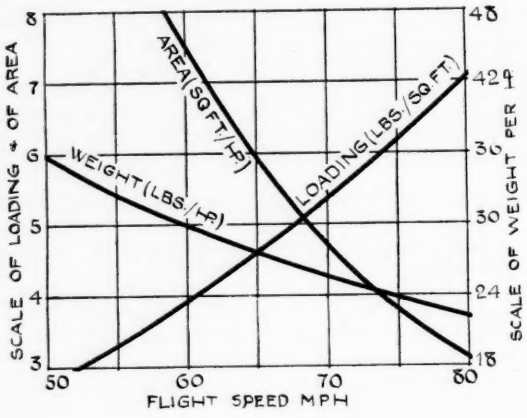
27. Now, for the machines in the Military Trials, we know X and we also have actual values for V. Dividing X by V, I shall, therefore, evolve a series of plausible values for k.

28. Having done so, I find k has a value in the order of ·5, that is to say, $\frac{1}{2}X = x =$ a speed appropriate to the design.

29. In selecting a certain value of k, I am selecting certain machines that have this factor in common but may differ in respect to W_1 and W_2.

30. One machine that has $k = 2$, exactly, has $W_1 = 23·7$ and $W_2 = 6·34$; an imaginary machine that plausibly might have $k = 2$ also, could be conceived with $W_1 = 24$ and $W_2 = 6·25$. For such a machine, $X = 150$ and $x = 75$ miles per hour. That is to say, at 75 miles per hour the lift of the wings is 6·25 lbs. per sq. ft.

31. Now let this imaginary machine possess the qualities set forth in the hypothesis of the opening paragraph, and construct a graph as there directed to illustrate the case.



32. This chart has two principal graphs, and a third that is derived from them.

33. The basic curves are weight per h.p. (W_1) and weight per square foot (W_2), both plotted to lbs. and m.p.h. The supplementary curve is their quotient expressing sq. ft. per h.p.

34. Taking the two basic graphs independently, their characteristics result from plotting $W_1 \propto V^{-1}$ and $W_2 \propto V^2$ respectively.

35. The function of k in respect of the chart is to locate the position of the loading graph (W_2) relatively to the graph of W_1, which is based on a resistance of $\frac{1}{6}$ of the weight, and a transmission and propeller efficiency of 80 per cent.

36. Given any weight per h.p., the chart indicates the appropriate speed x and the appropriate loading on the same ordinate.

37. Here are the values of x for the four machines under review :—

Hanriot 1	.. ..	$x = 77$ m.p.h. speed approximate to the wings.
Blériot sociable	..	$x = 66$,, ,, ,, ,,
Bristol 14	.. ..	$x = 90$,, ,, ,, ,,
Cody	.. ..	$x = 71$,, ,, ,, ,,

38. Having established a series of appropriate speeds, we can multiply them by their respective weights per h.p., and so can calculate the corresponding values of ϵ.

39. Thus :—

Hanriot 1	$\epsilon = 82$ per cent.
Blériot soc.	,, 72 ,,
Bristol 14	,, 97 ,,
Cody	,, 75 ,,

40. ϵ is the percentage of the power available that is required to fly the machine at its appropriate wing-speed, x, against a resistance of one-sixth of its weight.

41. Now let us compare ϵ with the actual efficiency, E_1, as calculated from the gliding resistance and the maximum speed.

42. Thus :—

Hanriot 1	Demonstrated	73 per cent.	E_1
Blériot sociable	,,	73	,,
Bristol 14	,,	81	,,
Cody	,,	69	,,

43. Reverting to para. 36, if the loading exceeds this value, the appropriate wing speed is increased, which necessitates anticipating more than 80 per cent. ε.

44. If the loading is less than this value, the appropriate wing-speed is reduced which leaves a margin of power in reserve.

45. If the loading is very much less, the large size of the machine may interfere with the realisation of a very high E_1, owing to disproportionate head resistance at high speeds.

46. Any departure from the exact value for W_2 involves a departure from the hypothesis of ε = 80 per cent.

47. The graph of W_1 is what the machine gets credit for doing when the actual efficiency is calculated on a resistance of 1 in 6. The graph of W_2 is an index to the wing effect on the ε anticipated.

48. To design for a low ε does not mean that one anticipates building an inefficient machine, but one that is making provision for a wide margin of power.

49. To design for a high e means that one is designing for high speed without reference to speed range.

50. In some respects, the design of a low ε machine is antagonistic to a realisation of a high E_1.

51. ε is derived from the product of kX and W_1, which is to say that it is a function of the product (weight per h.p.)^2. (weight per sq. ft.).

52. Since weight per h.p. appears in its second power, lightness is all-important in designing for a low ε, if the object is also to realise a high E_1.

53. The supplementary graph on the chart (area per h.p.) shows how far the power may be increased or reduced on a given machine without departing from the hypothesis.

54. Divide the old wing area by the new engine power to find the new index-point on the graph of area per h.p.

55. If the weight added or saved by the change in engines still keeps W_1 and W_2 within the limits prescribed by their respective graphs, where they are intersected by the new ordinate, the alteration is tenable.

56. The graphs, W_1 and W_2, show limiting values that comply with the hypothesis.

57. The graph (area per h.p.) is of secondary use in design, because the engines on the market are made to specific powers and the arbitrary selection of a motor is, therefore, an *initial* step in design, to which the wing area must be adjusted.

58. We will now consider each machine in the table :—

Hanriot.—If these machines were built mainly to fly fast against a 1 in 6 resistance, it was proper to design them for 80 per cent. ε. They realised a speed appropriate to their wings, and thus justified their design. In this I fail to find any support for the comment in the official report, which says the wings of these machines were " rather small."

Observe, however, that Hanriot 1 glided better than 1 in 6, and that its realised efficiency is less than the anticipated value. This indicates that either the resistance is increasing quickly with speed, or that the engine and propeller were unable to turn fast enough to take advantage of the low resistance. As Hanriot 2 has a higher gliding resistance at a higher gliding speed, it would seem as if the demonstrated efficiency for Hanriot 1 ought also have to been calculated on a higher resistance. In fine, these machines are well proportioned as to their basic dimensions, having regard to high speed being the purpose for which they were built.

Military Aeroplane Trials Analysis.*

	Effective H.P.	W_1.	W_2.	X.	x.	V max.	k.	G.	TV max.	ϵ%.	E_1%.	R%.
Hanriot 1 ..	80	24·0	6·4	153	77	75·2	·49	6·6	58·5	82	73	25·6
„ 2 ..	80	23·7	6·34	151	77	75·4	·50	5·9	64·9	81	81	13·2
Blériot tandem .	60	25·0	5·77	147	73	60·8	·41	5·6	43·5	81	72	17·5
„ sociable .	60	24·7	4·8	118	66	58·9	·49	5·3	44·0	72	73	47·3
Avro	65	27·2	5·28	144	70	61·8	·43	6·5	44·9	84	69	25·4
Bristol mon. (14)	75	24·5	8·75	214	90	70·5	·34	6·5	51·5	97	81	3·2
„ (15)	75	25·0	8·9	222	91	72·9	·327	—	—	100	—	26·0
British Dep. ..	80	24·2	6·3	152	76	68·2	·45	6·2	59·7	81	75	26·0
Maurice Farman	72	26·8	2·9	78	51	55·2	·71	6·8	42·3	61	58	47·6
French Dep. ..	80	23·4	6·1	143	75	69·1	·49	5·4	63·7	78	79	17·1
Cody	120	23·8	5·55	131	71	72·4	·55	6·2	83·5	75	69	49·4

* A more complete set of tables is available in the *British Military Aeroplane Trials*, published at the Offices of *Flight*, 6d.

SUMMARY OF ABBREVIATIONS AND FORMULÆ

X=(wt./h.p.) (wt./sq. ft.)
$=W_1 . W_2$
$=fV^{-1}.fV^2$
$=fV$
$\therefore kX=x=V$

$k=V$ max.$\div X$

$\epsilon=W_1x$
$=\cdot 5W_1{}^2W_2$
$=\cdot 5$ [wt./h.p.]^2[wt./sq. ft.]

TV max.=gliding resistance × max. speed

G=gliding resistance 1 in G

W_1=wt. per h.p.
W_2=wt. per sq. ft. wing loading
$X=W_1W_2=fV$
$x=kX$
V max.=actual speed
$\epsilon=W_1x$=percentage of the power available required to fly at x.
R%=speed range as an increase on minimum

59. **Blériot Tandem.**—The Blériot tandem was designed for 81 per cent. ϵ, which is justifiable in a high speed monoplane. It realised only 72 per cent. Unlike the Hanriot, however, its gliding resistance was high, and, in this case, it is the failure to attain the speed appropriate to the wings that is the cause of the low efficiency realised, as compared with the high efficiency anticipated. In fine, the Blériot tandem ought to fly faster than it does for its power, if it is intended for the high speed monoplane class.

The official report in referring to the 50-h.p. prototype of this model suggests that "it would appear that . . . considerable difficulties are experienced when a more powerful type is called for."

60. **Blériot Sociable.**—The Blériot sociable was designed for only 72 per cent. efficiency and demonstrated 73 per cent., as much as the tandem. It did not realise the flight speed appropriate to its wings. The speed range of the machine is very high for a monoplane, but an attempt was made in the trials to exaggerate the range unduly.

61. **Avro.**—The Avro was designed as a low-resistance biplane. Its gliding angle is good, but not such as to justify an anticipated efficiency of 84 per cent. The realised efficiency was 69 per cent., which is good for a biplane, but it was insufficient to enable the machine to fly at the speed appropriate to its wings.

If the machine had 15-h.p. more power for 100 lbs. extra weight, the new ϵ would be nearer to the present E_1, and the new appropriate wing speed would only be a reasonable increase on the present velocity attained.

The official report considers the machine to be "under engined," which I think is a justifiable comment. It reflects no discredit on the Green, the only British engine to go through the Trials, which put up a very fine performance, particularly in low fuel consumption.

62. **Bristol.**—These monoplanes were designed for low resistance in fast flight; their gliding angle is good, but still far steeper than would be required to justify an anticipated efficiency so high as 97 per cent. It led, however, to the realisation of 81 per cent. efficiency, than which no machine in the Trials did better. Even this high efficiency was totally inadequate to attain the high speed appropriate to the wings.

If 240 lbs. were taken off the weight in flight, the anticipated efficiency would still remain well over 80 per cent., and this is as much as might reasonably be removed from a machine that only weighs 25 lbs. per h.p. as it now flies under trial conditions.

Larger wings would be necessary to normalise the basic design with the present engine, but the present wings could be normalised by a larger engine if the added weight were sufficiently small, as shown by the aid of the chart.

The official report suggests that these machines should be somewhat lighter or flown without their full load.

63. **Deperdussin.**—The French Dep. monoplane was designed for 78 per cent. ϵ, and realised 79 per cent. efficiency on the basis of a gliding angle of 1 in 5·4. It did not quite realise the speed appropriate to its wings, so, apparently, the reserve power was mainly utilised in overcoming the comparatively high resistance indicated by the gliding angle.

The weight per h.p. in flight of this machine is the least of all those in the table, but the weight per h.p. of the unloaded machine is normal.

The official report considers that allowance for unfavourable conditions should be made in connection with the realised speed of this machine. This would improve its demonstrated efficiency and cause its genuine speed to be appropriate to the wings.

The British Dep. being heavier than the French Dep. anticipated slightly more efficiency than it demonstrated.

The Dep. is an excellent example of high speed monoplane design with well proportioned basic dimensions; it gained the second prize open to the world.

64. **Cody.**—The Cody biplane was designed for 75 per cent. ϵ, and realised 69 per cent. The apparently moderate margin of reserve, however, was sufficient to force the machine up to 72·4 m.h.p. which was just beyond the 71 m.p.h. appropriate to the wings. As the gliding speed was much below the maximum speed, there was a fine natural range of speed, which was still further increased by skilful flying, which reduced the minimum speed to 10 m.h.p. below the gliding speed.

Merely as an example of unusual dimensions, the Cody is a singularly interesting biplane design, and its performance thoroughly justified its award of the first prizes open to the world and to British construction.

65. **Maurice Farman.**—The Maurice Farman was designed for an exceptionally low $\epsilon = 61$ per cent., due to the use of very large wings carrying a very low loading. The efficiency realised was 58 per cent., also a low value, and evidently due to the large size of the machine putting an early limit on the maximum speed.

It is interesting to observe that the natural gliding speed is also the minimum speed. There is no other example of a machine in the list that does not have its minimum speed well below the gliding speed. It is clear, therefore, that the object of the Farman design was to be able to fly properly and easily at a very low speed, which it certainly does remarkably well.

Mr. Mervyn O'Gorman: Mr. Berriman's investigation of the Military Aeroplane Competition is useful so far as it gives a co-ordination of the results. His observation that in all cases the weight per horse-power came out at a figure near 24 lbs. is an example.

This observation also shows to a certain extent the superiority of the aeroplane over the motor car in its power equipment, since cars were found to accelerate well, and climb well, if they possessed one horse-power per cwt. of rating—I suppose the liveliest modern touring car could not develop much more than one horse-power per 50 lbs. weight. Similarly it was an interesting outcome of the lecturer's method of looking at the competition results to find that the wing loading, though it averaged roughly five or six lbs. per square foot, nevertheless touched the extremes of 9 lbs. per square foot and 3 lbs. per square foot.

While appreciating many of his remarks in view of the way they facilitate a survey of the trials, and the gathering of information from them, I cannot accept as really useful his X and ϵ.

I will take as an example one of the elements which are involved.

We write horse-power as $\frac{\text{foot-pounds}}{\text{time}}$ and taking the $\frac{\text{foot}}{\text{time}}$ element separately, as the lecturer did, we can consider the product of the aeroplane's velocity and the pounds force opposing it as an expression of horse-power used.

The Military Aeroplane Competition observations gave us the aeroplane's maximum velocity, and by the gliding test an attempt to measure its minimum resistance. These measurements were by no means simultaneous, nor if they had been, would the results desired have been obtained. For an aeroplane with an engine which has, as it should have, a good margin of power for climbing, effects its maximum flying speed at a velocity different from and substantially superior to that of minimum resistance. Not only that, but during the gliding test the propeller's head resistance is being measured, and this is an important factor introducing variants which entirely falsify any results in which it is neglected.

Moreover, even if the product of the resistance and speed taken simultaneously during any one flight were available it would be quite unfair to compare the horse-power so calculated with the horse-power developed by the engine on the bench, and, still worse, to do this for a number of aeroplanes, and so get a figure of comparison between them.

It is essential that the horse-power used for comparison be the horse-power which was being developed at the time of the simultaneous measurements. What I wish to point out is that by taking the horse-power of the engine, the maximum speed and the gliding resistance, as he has done, the lecturer is assuming a number of matters to be practically constant whereas their inconstancy is a cardinal, if not the chief, matter with which the aeroplane designer is concerned. Hence the deductions, though useful for a bird's-eye view of a particular trial, are not so for any purpose of design that I can see.

The amount of horse-power which the designer had assigned for accelerating, for quick climbing, for restituting the velocity lost in combating gusts, by warping and ruddering—all these are lumped together in a manner which, though it effects a simplification, relieves the conclusions summarised as E_1* of any clear significance. Even if the amount of horse-power reserved for climbing had been deducted, Mr. Berriman would have had a great deal of work, but the result could still not be used, since the climbing speed is not the maximum speed and he is dealing with the horse-power at the maximum flying velocity. I will not press this any further because, in spite of these remarks I think the Society owes Mr. Berriman a debt of thanks for the survey he has so carefully made of the trials, and for the very suggestive way he has considered them and analysed them.

Mr. Archibald R. Low: I must agree with Mr. O'Gorman, that Mr. Berriman's methods are open to criticism. He seems to have attempted to expose, in a simple way to the layman, engineering quantities which are in themselves and in their relations highly complex.

To do this he has introduced a quantity X which he says has virtually the dimensions of velocity.

But its dimensions actually are :—

$$\frac{\text{Weight}}{\text{Horse-power}} \times \frac{\text{Weight}}{\text{Surface}} = \frac{mlt^{-2}}{ml^2t^{-3}} \times \frac{mlt^{-2}}{l^2} = ml^{-2}t^{-3}$$

No current physical quantity has these dimensions, which are those of density multiplied by hyper-acceleration! I prefer to follow the classical French method which I have set out in notes that I shall hand to the secretary.

These figures are not directly applicable to the actual detailed design of an aeroplane, but are of the utmost value in showing the designer in what direction he can advance.

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*I wish to point out that I have made *no* comment on the use by the lecturer of the word "efficiency" in a popular manner instead of in the strict sense of *ratio of output to input* which is more usual in scientific meetings as distinct from other occasions.

NOTE ON THEORY OF AEROPLANE DIMENSIONS

We may start from the following relations :—

Variables.	Quantity represented.
x	Horse-power of engine.
y	Square root of supporting surface.
z_1	Weight of "power plant" including fuel, reservoirs, piping, radiators, water, instruments fitted to motor, &c.
z_2	"Glider" weight or weight of complete machine including all aerodynamical instruments, but excluding pilot, passengers, guns, ammunition and power plant.
z	"Useful" weight, pilot, passengers and all material not permanently installed either on aeroplane or on motor.
Z	Total flying weight.
K_y	Coefficient of sustentation.
K_x	Coefficient of resistance (for whole machine).
ρ	Propeller efficiency.
c	Coefficient of loading.
V	Aeroplane speed.

We may further define three useful coefficients :—

$$\text{Coefficient of power plant weight* } k_1 = \frac{z_1}{x} = \frac{\text{power plant weight}}{\text{motor horse-power}} \quad (1)$$

$$\text{Coefficient of glider weight† } k_2 = \frac{z_2}{cy^3} \quad (2)$$

$$\text{Where coefficient of loading } c = \frac{z}{y^2} = \frac{\text{total weight}}{\text{surface}} \quad (3)$$

Finally :—

$$Z = z_1 + z_2 + z$$

$$\text{or useful load } z = Z - z_1 - z_2 \quad (4)$$

In addition we have the aerodynamical relations which depend only on the external form of the aeroplane.

$$z = K_y S V^2 \quad (5)$$

$$x = \frac{K_x S V^3}{75\rho} \quad (6)$$

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* The total power plant weight may be divided into four terms :—

i. Bare motor weight .. .. =m

ii. Percentage allowance for revolution counters, petrol pipes, controls, etc., etc. .. .. =m×a%

iii. Oil and petrol supply per hour × hours' duration .. .. =p×t

iv. Percentage allowance for tanks and tank supports .. .. =p×t×b%

The first two terms are roughly proportional to horse-power, but independent of duration of flight.
The second two terms are proportional to horse-power × hours.
Hence total weight $Z_1 = m(1+a\%)+p\times t(1+b\%)$

† For geometrically similar machines the glider weight increases as the cube and the resistance of the members to stresses only as the square of the dimensions.

Hence to maintain the same factors of safety the total load must increase only as the square of the linear dimensions, that is as the surface.

Hence the loading c must remain constant.

If the members are tubes or shaped out girders the strength of the ○ I members and the glider weight may both be increased in the same proportion and the loading c, may also be increased in the same proportion to a close approximation without appreciably altering the external dimensions of the aeroplane.

All these conditions are implied in the equations (2) and (3).

If, however, the members are solid, their resistance to compression and tension increases as the square of their thickness, but their resistance to buckling as the cube, and the above equations become modified.

We have also the obvious relation :—

$$y^2 = S \tag{7}$$

We have thus nine variables, x y z_1 z_2 z Z c S V; five coefficients, k_1 k_2 K_y K_x ρ; and seven equations.

$$z_1 = k_1 x \tag{1}$$
$$z_2 = k_2 c y^3 \tag{2}$$
$$Z = c y^2 \tag{3}$$
$$z = Z - z_1 - z_2 \tag{4}$$
$$Z = K_y S V^2 \tag{5}$$
$$x = K_x S V^3 \div 75\rho \tag{6}$$
$$y^2 = S \tag{7}$$

By means of the seven equations we may eliminate any six variables and obtain a single relation between the remaining three.

Let these three be x y and z, and the relation :—

$$z = f(xy)$$

To find a maximum value of z we write :—

$$z'_x = f'_x = 0$$
$$z'_y = f'_y = 0$$

and between these three equations we may find the values of x and y corresponding to a maximum value of z.

We may proceed thus :—

From (5) and (6) using (7)

$$\frac{Z^3}{x^2} = \frac{75^2 \rho^2 K_y^3}{K_x^2} y^2$$

$$Z = A x^{\frac{2}{3}} y^{\frac{2}{3}} \quad \text{where} \quad A^3 = \frac{75^2 \rho^2 K_y^3}{K_x^2} \tag{8}$$

Using (3) $$c = A x^{\frac{2}{3}} y^{-\frac{4}{3}} \tag{9}$$

From (2) and (9) $$z_2 = k_2 A x^{\frac{2}{3}} y^{\frac{5}{3}} \tag{10}$$

(1) is $z_1 = k_1 x$

From (5) $$V^2 = \frac{Z}{K_y S} = \frac{A x^{\frac{2}{3}} y^{\frac{2}{3}}}{K_y \; y^2} = \frac{A x^{\frac{2}{3}} y^{-\frac{4}{3}}}{K_y}$$

$$V = A^{\frac{1}{2}} K_y^{-\frac{1}{2}} x^{\frac{1}{3}} y^{-\frac{2}{3}} \tag{11}$$

From (4), using (1) (8) (10).

$$z = A x^{\frac{2}{3}} y^{\frac{2}{3}} (1 - k_2 y) - k_1 x \tag{12}$$

Thus z z_1 z_2 Z c S V are all solved in terms of x,y and of the coefficients k_1 k_2 K_x $K_y \rho$, the solutions being given in equations (12), (1), (10), (8), (9), (7), (11).

From (12) for a turning value of z :—

$$\frac{dz}{dx} = \tfrac{2}{3} x^{-\frac{1}{3}} A y^{\frac{2}{3}} (1 - k_2 y) - k_1 = 0 \tag{13}$$

$$\frac{dz}{dy} = \tfrac{2}{3} y^{-\frac{1}{3}} A x^{\frac{2}{3}} \left(1 - \frac{5}{2} \frac{y}{k_2} \right) = 0 \tag{14}$$

rejecting $y = \infty$ $x = 0$ as solutions of (14) we get the well-known result :—

$$y_0 = \frac{2}{5k_2} \tag{15}$$

as the surface with which maximum weight can be lifted independently of all conditions save the method of construction, the materials used and the factor of safety allowed.

Substituting this value in (13) which may be written :—

$$x^{\frac{1}{3}} = \tfrac{2}{3} A y^{\frac{2}{3}} \frac{1 - k_2 y}{k_1}$$

we get $x_0 = (\tfrac{2}{5})^5 \dfrac{A^3}{k_1^3 k_2^2}$ (16)

From (8) $Z_0 = A x_0^{\frac{1}{3}} y_0^{\frac{2}{3}}$

$$z_{10} = (\tfrac{2}{5})^4 \frac{A^3}{k_1^2 k_2^2} \tag{17}$$

From (1) $z_{10} = K_1 x_0$

$$z_{10} = (\tfrac{2}{5})^5 \frac{A^3}{k_1^2 k_2^2} \tag{18}$$

$$= \tfrac{2}{5} Z_0$$

From (3) $c_0 = \dfrac{Z_0}{y_0^2} = (\tfrac{2}{5})^4 \dfrac{A^3}{k_1^2 k_2^2} \times \dfrac{k_2^2}{(\tfrac{2}{5})^2}$

$$c_0 = (\tfrac{2}{5})^2 \frac{A^3}{k_1^2} \tag{19}$$

From (3) and (7) :—

$$z_{20} = k_2 c_0 Y_0^3$$

$$= k_2 (\tfrac{2}{5})^2 \frac{A^3}{k_1^2} \times (\tfrac{2}{5})^3 \frac{1}{k_1^3}$$

$$z_{20} = (\tfrac{2}{5})^5 \frac{A^3}{k_1^2 k_2^2}$$

$$z_{20} = \tfrac{2}{5} Z_0. \tag{20}$$

From (4), (17), (18), (20) :—

$$z_0 = Z_0 - z_{10} - z_{20}$$

$$= Z_0 (1 - \tfrac{2}{5} - \tfrac{2}{5}) = \tfrac{1}{5} Z_0 \tag{21}$$

Hence, for arbitrarily constant values of k_1 k_2 K_x K_y, ρ a maximum useful weight is lifted when the motor weighs $\frac{2}{5}$, the glider $\frac{2}{5}$, and the useful load $\frac{1}{5}$ of the total weight.

As usual in dealing with engineering maxima a pretty wide range of values on either side show very little falling off from the maximum value of useful weight.

CONSTANT "BEST" SURFACE

Taking $\rho = \cdot 70$, $K_y = \cdot 03$, $K = \cdot 005$, $k_1 = 4, k_2 = \cdot 07$ as values occurring in practice, we get approximately :—

$y = 5 \cdot 72$ constant
$A^3 = 3000$
$A = 14 \cdot 5$
$Z = 47 x^{\frac{1}{3}}$
$z = 27 \cdot 7 x^{\frac{1}{3}} - 4x$
$V = 6 \cdot 76 \ x^{\frac{1}{3}}$ using metre kilogram second units throughout.

Plotting these and $\frac{z}{Z}$ against horse-power we get the following tables, which may be plotted with advantage as an exercise.

x	Z	Z	V	$\frac{z}{Z}$
0	0	0	0	·59
10	217·5	88	14·55	0·404
20	346	124	18·33	0·358
30	453	146	21·00	0·322
40	549	163	23·1	0·297
50	637	175	24·9	0·275
60	721	185	26·45	0·257
70	797	190	27·85	0·238
80	870	193	29·1	0·222
90	942	195	30·25	0·207
100	1010	196	31·3	0·194
110	1080	195	32·4	0·181
130	1204	189	34·2	0·157
150	1330	182	35·9	0·137
170	1440	168	37·4	0·117
200	1605	146	39·5	0·091
230	1765	120	41·4	0·068
260	1912	87	43·1	0·046
300	2100	38	45·2	0·018
330	2240	0	46·7	0

We see that the useful weight rises to a definite maximum and then falls to zero for a certain value of the horse-power x. Above this value the motor is unable to raise its own weight even without pilot or passenger on board.

Again the ratio z/Z starts at a definite value, ·59, and falls steadily to zero.

Hence the greater the horse-power, the less the *proportion* of useful weight lifted.

Increase of horse-power leads to an increase of speed proportional to the cube root of the horse-power only, and this continues throughout the whole range of possible values.

Below the turning value increase of horse-power gives increase of speed and useful load.

At the turning value increase of horse-power gives increase of speed, while the useful load remains constant.

Above the turning value increase of horse-power leads to increase of speed accompanied by decrease of useful load.

All these conclusions are subject to the condition that the surface is constant.

A much more usual condition is that of constant power.

This arises from the rigid standardisation of motors, and the extreme flexibility of dimensions in aeroplane design.

CONSTANT HORSE-POWER

$x_0 = 100$ h.p. constant

with the same values of ρ, K_y, K_x, k_1, k_2 as before

$z_1 = 400$ const.

$Z = 313y^{\frac{1}{3}}$

$z = 313\ (1 - \cdot 07y)y^{\frac{1}{3}}$

$V = 30{\cdot}6y^{-\frac{1}{3}}$

$c = 313y^{-\frac{1}{3}}$

$S = y^2$

y	S	Z	c	z
0	0	0	∞	—
1	1	313	313	—109
2	4	496	124	26·5
3	9	650	72	113.6
4	16	785	49	165
5	25	910	36·4	197
6	36	1030	28·5	198
7	49	1144	23·4	183
8	64	1254	19·6	152
9	81	1360	16·8	105
10	100	1450	14·5	30

COMPARISON OF ARMY TRIAL MACHINES

The following table has been made out from the published results of the Army Trials, [k_1 and k_2 are as defined above.] There is considerable difficulty in assigning certain items of weight as between the power plant and the glider, but the nature of the results is not greatly affected.

K_{yg}, K_{xg} are the coefficients of sustentation and traction, V_g is the aeroplane speed, T_g is the traction, P_g the horse-power expended during the glide, $P_g \div \cdot 7$ the approximate motor power required at propeller efficiency ·7, all at the best gliding angle. Since at a turning value the traction is stationary the horse-power is nearly proportional to the velocity in the neighbourhood of the test gliding velocity. Hence, multiplying the motor power ($P_g \div \cdot 7$) by the fastest observed speed and dividing by the best gliding speed, we get a value for the motor-power at maximum speed not very much lower than the power actually required. This value is shown in the column P^1 max.

The maximum rated power is shown in the column P max.

Name	k_1	k_2	K_{yg}	K_{xg}	V_g	P_g	$\frac{P_g}{\cdot 7}$	P^1max	P max
100 Gnome Hanriot I.	4·3	·084	·0384	·0048	28·8	42	60	76½	80
70 Gnome Bleriot Tan	4·2	·067	·0485	·0080	24·2	36·2	51·8	58·8	62
60 Green Avro ..	4·7	·077	·0295	·00414	28·2	42	60	56	60(?)
80 Gnome Bristol ..	3·62	·11	·053	·00785	28·5	47·2	67·5	74·5	75
75 Renault M. Farman	4·8	·052	·047	·00524	17·5	22·6	32·5	47	75
120 Daimler Cody ..	4·46	·065	·0345	·00515	28	68	97	112	120

It will be noted that the Bristol is by far the most heavily constructed machine in the table. If the design is as good as that of the other machines it should also be the strongest, with over twice the factor of safety of the Maurice Farman. Bad design on the other hand will increase the weight without a corresponding increase in the factors of safety.

It will be observed that the Cody machine (relatively to the stresses involved of course) is actually lighter than the Bleriot in construction although it is officially described as being of very strong construction.

The Avro, as indicated by the figures, is so under-powered that it cannot attain its best gliding speed while flying level under its motor power.

The Maurice Farman figures are so anomalous and the check of P max. against P^{1}max. fails so completely that the best gliding ratio, 1 : 9, must be seriously questioned, and should probably be only 1 : 7 approximately.

As a further example of the range of possible design with a given motor the Bristol may be taken as given in the Army trials report.

Bristol Monoplane—

$x_o = 75$ H.P. = constant
$k_1 = 3{\cdot}62$ = constant
$k_2 = 0{\cdot}11$
$K_{yg} = {\cdot}053$
$K_{xg} = {\cdot}00785$
$A^3 = 6700$
$A = 18{\cdot}2$
$z_1 = 272$ constant
$Z = 310y^{\frac{3}{3}}$
$c = 310y^{-\frac{1}{3}}$
$z_2 = 34{\cdot}4y^{\frac{5}{3}}$
$V = 76{\cdot}5y^{-\frac{2}{3}}$

The following table shows the variation of these quantities with the linear dimensions:—

y	S	Z	c	z_2	z	V
0	0	0	0÷0	..	..	..
1	1	310	310	34·2	— ·2	76·5
2	4	494	123	108	114	48·2
3	9	645	72	214	159	36·8
4	16	780	48·7	343	165	30·4
4·4	19·4	830	42·8	402	156	28·5
5	25	910	36·4	500	138	26·2
6	36	1022	28·4	675	75	23·1
7	49	1140	23·3	880	— 12	20·8

It will be noted that the high loading of the Bristol is the direct and necessary consequence of its high specific glider weight.

According to the above table a slight advantage in both speed and useful load would be obtained by taking y = 4 instead of y = 4·4, the actual figure.

Then the surface would be less, the loading speed and useful load greater.

Brigadier-General Henderson, in response to a request for his views, said that as one of the judges in the trials he could not make any comment on the results. The judging of the machines was undertaken as a military duty and was confined to the actual results obtained. No account was taken of the designer's intentions, only of what he achieved. It was worthy of note that the machines which did best were not specially designed for military purposes.

Brigadier-General F. G. Stone: We have heard a good deal about the mechanical efficiency of aeroplanes, and Mr. Berriman has endeavoured in his paper by the aid of mathematics, to give us a ready means of correlating the various mechanical factors which in combination produce a greater or less degree of efficiency; but there is one factor which has all along been too much ignored, and that is the *human* factor: this is a factor which cannot readily be reduced to terms of "x" but it is none the less a very important one.

For the last three years there have been plenty of aeroplanes which were capable of flying well enough to train our airmen to a degree of perfection, which would have produced a far larger number of highly skilled pilots than we now have available, if the fullest use had been made of the facilities obtainable. But our policy was to wait for the perfected machine before we attempted seriously to perfect the pilot.

It is quite erroneous to attribute the bulk of the results now obtained in the air to recent improvements in machines; these results are to be attributed far more to the higher training and experience of the pilots. The machines have been improved in details of construction, but no revolutionary improvements have been effected in principle. The machine with which Cody achieved his remarkable successes at the Military Trials, is practically the same machine in which he struggled against adverse criticism three years ago—but it is not the same Cody. It is the man and not the machine which has made the greatest strides in the last three years, and the man who has had the greatest experience and has a natural gift for flying will achieve finer results from *any* machine, than the less experienced and less gifted man with the most ideally perfect machine in the world.

I am not suggesting that we should relax our efforts to obtain greater perfection in the machines, but I am urging that we should not allow ourselves for a moment to relax our efforts to train and to go on training, persistently, continuously, as many pilots as we possibly can, and to make them as perfect as they can be made.

LIEUT. W. PARKE: In my opinion in considering the Military Trials, one great mistake has been made. It appears to be universally considered that the possession of a good gliding angle is a great assistance in making an involuntary descent when flying cross-country.

I suggest that this idea is entirely erroneous; true, a good gliding angle will enable one sometimes to reach the only available landing-place, but in the great majority of cases there is no difficulty in reaching a landing-place of sorts. The pilot, unless of exceptional ability, dare not cut things too fine and prefers to come down rather steeper than his gliding angle so as to be on the safe side and have something in hand; then when he levels out, the extra speed that his good gliding angle gives him prevents him from getting on to the ground, but keeps him skimming along perhaps into the next hedge. The performance of Weyman's Nieuport (100 Gnome) may be instanced as an example of this. The point I am driving at is that a very fine gliding angle and big speed variation may be extremely valuable in the hands of a pilot of exceptional skill, but the average pilot when faced by an involuntary landing dare not risk hitting the near hedge by an error of judgment in utilising his slow speed and so skims on into the far one. A machine on which one can come down anyhow and just straighten out and land right away is far preferable for cross-country work.

Most machines have shown in the trials that, landing voluntarily, they could pull up in very short distances; the problem is, therefore, not so much as to how to pull up on the ground, but how to get on to the ground.

To do this some means of "artificially spoiling the gliding angle" is required.

MR. A. V. ROE pointed out that the landing of a high-speed aeroplane with good gliding angle could be greatly facilitated by reversing the propeller when a few feet off the ground, thus checking speed very rapidly.

MR. HANDLEY PAGE asked how it would be done.

MR. ROE replied: "By controlling the angle of the propeller blades, as in a marine launch."*

THE CHAIRMAN: Ladies and Gentlemen, when I received an invitation from the Aëronautical Society of Great Britain to take the chair to-night, I was very pleased, for although I knew that I was extremely ignorant of the technicalities of aircraft, I was only too anxious to have an opportunity as a General in the Army of showing my deep interest in the subject and my appreciation of the fact that aircraft are going to take a very prominent position in the wars of the future. I think myself that the subject is so important to the Army that it would have been more appropriate if the Chief of the General Staff, Sir John French, had been in my place. At the same time, I should have had a feeling of regret, as if he had been here I could not have been. When I talk on the subject of flying and encourage others to take it up, I own to a feeling of meanness, for it is not altogether pleasant to be egging on others to do what I confess I dare not

* [This idea has often been suggested for aerial work, *e.g.*, Duray's reversing propeller.—ED.]

do myself. In war, matters are very different, for it often happens that a General has to send troops forward to the assault whilst he himself is in a position of comparative safety—but, in peace time, to urge gallant fellows to risk their lives every day, is not a very congenial task. At the same time, we must encourage those who have the enterprise and pluck to come forward and learn to pilot the vessels of the air, for it is an undoubted fact that aeroplanes are probably going to revolutionise future warfare, and the nation which is not properly equipped with aircraft and has not a large supply of highly trained pilots will find itself very seriously handicapped at the outset.

I think everyone has been very much struck with the thoroughness of the recent trials. You will, I am sure, all agree with me that we could not well have had a more poisonous summer for them, and perhaps you will also agree with me that the rough weather was, as it happened, a blessing in disguise, for we were able to prove that aircraft had made such advances that they had become almost independent of weather. It seemed to me, no matter how hard it blew, or how much it rained, the trials still went on, and that the plucky pilots were ready to take their turn no matter how rough it was —and that, in spite of this, there was not a single accident in any of the competitions. Cody's win was, I admit, a source of pleasure to me, for I claim indirectly to have had a good deal to do with his success. I was at Aldershot when he received his *congé* from the War Office, as the authorities had come to the conclusion that he had taught us all there was to be learnt about kites and balloons, and that he was not sufficiently advanced in his knowledge of aeroplanes. Mr. Cody came to me in great despair and asked to be allowed to remain on and use Government ground for his experiments. This I readily did, and shortly afterwards received an order from the War Office that I must withdraw my permission. I went to the War Office, and fought for him, and eventually got the authorities to agree to his being allowed to remain there and fly on paying a nominal rent. General Stone has remarked to-night on the extraordinary way in which he improved in skill and nerve year by year ; to this I would add in his powers of invention and improving his machine. I opened my remarks by saying that I was quite unable to discuss technicalities. We have indeed listened to a very able and interesting discussion, but I own that a good many of the figures and formulæ were a good deal beyond me, and I secretly hope beyond other people in the room as well. It is for us Generals to consider only the practical and tactical use of machines. It is for the inventors and manufacturers to produce the machines. The strides made in the last few years have really been enormous, but there is still a very great deal to be learnt, from my point of view, as to their tactical use. The manœuvres this year taught a good deal in this direction. They showed us how it was possible, with armies some 60 miles apart, for the opposing flying corps to obtain for their respective commanders most accurate information of the localities of the hostile troops within three hours of the commencement of hostilities. If this state of affairs was to become normal and usual in war time, the effect on the employment of our cavalry would be a very great one. I am now speaking for the benefit of those who are not soldiers in this hall, and will explain that at the outset of a campaign masses of cavalry have to be employed on what we call long strategical reconnaissances, covering hundreds of miles very often in a few days, and anyone will easily understand how worn-out those horses get and that, when the time of battle comes, it must often happen that the cavalry is so stale that it could do little in the actual fight. What we want to know is—Can we rely on our aeroplanes in future to such an extent that we can hold our cavalry in hand so that they may be fresh and available to take a very active part in the battle alongside the other arms ? In the future, we shall no doubt see the arming of aeroplanes taking an important position. How will aeroplanes when armed attack each other ? How will they keep hostile aeroplanes at a distance and prevent them getting information of their own troops ? Will they ever become seriously effective for offence by using bombs ? Then again, how will it be possible for airships to recognise hostile airships ? Will they be very vulnerable ? Will guns be invented which will make it a serious danger for them to fly over hostile troops ? All that we know at present from actual experience in war is that in Tripoli, the Italians have made a very considerable use of aeroplanes for reconnaissance purposes without apparently any casualties. In the war which is now going on we hear very little except newspaper reports that Bulgarian aeroplanes have constantly flown over Adrianople,

and that the Turks have expended a very great deal of ammunition on them without any results. All this is hopeful, as it would be a terrible thing to think that pilots, who already run such risks in their actual work of driving their aeroplanes, should have added to their dangers that of being very liable to be brought down by hostile fire. Then, again, if hostile fire is really dangerous, will it be possible to armour-plate the seats occupied by the pilot and the observer in such a way as to render them more or less safe? All these are points on which we want information and which further experience alone can bring. We are, however, decided on one or two points. One important one is that the observer must be a trained man. By a trained man I mean one who is thoroughly in touch with all military formations and who is able to bring back to his commander an accurate account of the troops he has seen and who can describe them in such a way as to make himself clear. It has been suggested to me by one of our coming pilots—who I am glad to see present in this room—that it is advisable that a General Staff Officer, in the confidence of his General, should as far as possible be used as an observer, and in this proposal I think there is a very good deal of common sense, for he will know exactly what to look for, what sort of information his General wants, and will be able to bring it back to him. Again, in the course of an action, it may happen that the General wants particular information of a certain part of the battlefield. He tells the General Staff Officer to jump into an aeroplane, go off, and find it out, and he will feel sure of getting the very information he seeks for. Another use of aeroplanes which was tried on these manœuvres with success was as despatch carriers. Now, to explain this, I will take a small example. I may imagine that I am commanding a force in the field, extended, as all modern fighting is, over many miles of front. I am in a position of vantage. I observe some movement of the enemy, perhaps three or four miles off, and I see that the opportunity is fleeting, and I want at once to send troops to take them in flank, to counter-attack, or to do something. Without aeroplanes, I have no means of getting my message through to the troops I want to move in sufficient time. With an aeroplane, I merely say—Have a message written to Brigadier-General So-and-So, in a certain village perhaps three or four miles off; and I send this off by the aeroplane, and in three or four minutes it is in the hands of the man for whom it is intended, and he is able to move at once and carry out the desired operation. This year we have certainly made enormous strides, as I said before, in ascertaining the limitations of aircraft, but we have been a great deal handicapped on Salisbury Plain by the existing by-laws, which allow artillery to shoot only at certain times during the day. Now I think it is accepted that the time of day which above all others is suitable for flying is the very early morning, just after dawn. Under existing rules, we are not allowed to shoot until nine o'clock, but we are trying to arrange with the local County Councils to have permission to shoot on six or eight days of the month from dawn, for it is very necessary that aeroplanes should be constantly working with artillery in action. We hope that in this way we may get experience of how to obtain and send information of where the hostile troops are located, and also learn to direct our fire accurately by what the observers in the aeroplanes tell us. This permission to shoot in the early morning, if obtained, will enable us to carry this out. It is, however, impossible to expect any great efficiency in flying corps unless a considerable amount of money is spent on them. In France, for instance, they are spending I think about a million this year. We spend very little at present, but are spending more and more each year, and we may congratulate ourselves on having a Secretary of State for War who places efficiency in aircraft so far forward as he did in his Guildhall speech. One great advantage has already resulted from the institution of the Flying School at Upavon. We have for years been trying to bring the two Services—the Navy and the Army—more into touch with each other. It has been a difficult thing to accomplish, and it is not altogether accomplished yet. But those who are not in touch with military affairs will easily realise how improbable it is that any warfare can take place in which Great Britain is taking a part, which does not involve the working together of the Navy and the Army, and that no machine can work perfectly unless all its parts are accustomed to work together and are constantly practised therein. Now, at the Flying School, I am glad to say that the Navy and the Army are in daily touch and have already got to appreciate each other's value. At present they are working together indiscriminately, but I hear a rumour that it is suggested that they shall be separated

and work as separate corps—a Naval Corps and a Military Corps. I sincerely hope that if the authorities are thinking of doing this they will change their mind, and let things remain as they are at present. I have only one more remark to make, and that is with regard to what has been brought out this evening and in the report on the Army trials, in connection with the manufacturing of the machines. It is evident that at present we have to depend to a great extent on the production of parts from foreign countries. I know that our manufacturers are making every effort to produce satisfactory machinery, &c., entirely of British make. I only hope this may be pursued and may be successful, as, in war materials at any rate, there should be no doubt about our being able to supply ourselves with the very best that can be produced at the hands of the manufacturers in our own islands. There can be no doubt, I think, that our British pilots in courage and skill are second to none, and I look to the day when we may be able to say the same of the engines and necessary parts of the machine. I will now conclude by asking you to join me in a vote of thanks to Mr. Berriman for having so ably opened the discussion, to Mr. O'Gorman and Mr. Low and others for having continued it, and finally I will express my own thanks to the Aëronautical Society of Great Britain for having given me the opportunity of showing the high value I place on aeronautics for military purposes, by asking me to take the chair this evening.

On the proposition of Major-General R. M. Ruck, C.B., a hearty vote of thanks was unanimously accorded to General Sir Horace Smith-Dorrien for presiding, and the meeting then terminated.

For the photographs of the machines in the Trials, of which slides were shown at the beginning of the meeting, the Council are indebted to the courtesy of the Editors of *Aero* and *The Aeroplane*, and Messrs. The Blériot Aeroplane Co., Bréguet Aeroplane Co., British and Colonial Aeroplane Co., British Deperdussin, A. V. Roe and Co., and Capt. H. F. Wood.

"CENTRES OF PRESSURE IN AERONAUTICS"

A Communication to the Research Committee, by B. MELVILL JONES, B.A., A.F.Aë.S.

Definition of "centre of pressure." The problem of correctly defining the forces acting upon a body, such as an aeroplane, moving through the air is one of some complexity and there are a great number of apparently different but actually equivalent methods by which the forces can be determined or recorded. Considerable difficulty is often experienced by those who are not familiar with the laws governing the composition and resolution of forces, in grasping the meanings of the quantities involved, and the following short treatise on the subject is an attempt to make the matter as clear as possible from a practical point of view and, at the same time, to indicate the methods most commonly adopted.

It has become a common practice to talk in a general way of the "centre of pressure" of an aerofoil or other body without any further statement as to what precisely is meant by the term. Rigidly speaking this is, of course, quite incorrect. The only real meaning that could be attached to the words, used without further qualification, would be some point, analogous to the centre of gravity, through which the resultant air force would always act, no matter from what direction the relative wind may blow. Such a point does not of course exist for any body except a sphere, in which case it lies at the centre.

When, however, we speak of the centre of pressure of an aerofoil, we generally mean the point where the resultant of the air forces on it cuts some plane, imagined to be rigidly fixed to the aerofoil, and this plane is almost always supposed to be the plane containing the chords, if such a plane exists for the aerofoil considered, although any specified plane of reference could conceivably be used for the purpose. When defined in this way the term centre of pressure has a real meaning, and in the ordinary course of events this definition is tacitly implied when the term is used.

It is found experimentally that, for an aerofoil, the position of the centre of pressure, thus defined, varies considerably with change of angle of incidence, but that it is, to a first approximation, independent of the wind velocity.

Determination of centre of pressure. In general it requires six separate measurements to find the resultant, in three dimensions, of a number of forces, acting upon a body. If, for instance, the body be referred to three axes at right angles it is necessary to measure the three forces along the axes and the three couples about them. In all cases, however, in which the body has a plane of symmetry and the direction of flight is parallel to that plane, three things are known about the resultant automatically, and only three measurements have to be taken to fix the resultant.

The three things that are known automatically, under the above conditions, are :—

I. That there is no component of the resultant, normal to the plane of symmetry, or, in other words, that the resultant lies in the plane of symmetry.

II. That there is no couple about an axis parallel to the direction of flight and in the plane of symmetry.

III. That there is no couple about an axis perpendicular to the direction of flight and in the plane of symmetry.

Conditions two and three are, of course, equivalent to saying that there is no couple about any axis lying in the plane of symmetry.

We are left, therefore, in the symmetrical case just considered, with a force problem in two dimensions, which is simply to fix the magnitude of the resultant and its line of action in the plane of symmetry ; and to do this three different measurements, and only three, are required. Theoretically any three measurements are sufficient to fix a force in two dimensions, but practically, care must be taken to ensure that sufficient accuracy can be obtained.

It is an elementary rule of mechanics that a force F acting upon a body along any given line, is exactly equivalent to an equal and parallel force acting at a distance l from the original line of action of the force together with a couple Fl tending to turn the body. When observing and recording the forces acting upon aerofoils, etc., use is continually

made of this rule, for from it we can see that the resultant may be considered either as varying its position in the plane or as passing through some definite point and being accompanied by a varying couple. For instance, the two forces F and F_1 in Fig. I acting along lines A B and A_1 B_1 may either be considered to act along these lines or to act along parallel lines passing through the fixed point O and to be accompanied by couples Fl and F_1l_1 respectively.

We see then that, in the symmetrical cases discussed above, the resultant air force can be either determined or recorded in any one of the following ways :—

1. By giving its magnitude, and its line of action in the plane of symmetry, by some graphical method.

2. By giving its magnitude and direction and supposing it to pass through some fixed point and giving the corresponding couple.

3. By giving its magnitude and direction and fixing its position by giving the point of intersection of the line of action with a fixed line, generally the chord.

The most usual method of defining the magnitude and direction of the resultant is to record the values of its two components along two lines at right angles, and these two lines are generally taken perpendicular and parallel to the relative wind direction, in which case the components are known respectively as the Lift and Drift. It then only remains to fix the line of action of the resultant by one or other of methods two or three.

Methods usually adopted. The methods adopted at the various aeronautical laboratories, both for observing and recording air forces upon various bodies, serve as good illustrations of the above principles, especially as in most cases the results are obtained by some methods suitable to the apparatus available and then converted by calculation and recorded in whatever manner appears to be most convenient for practical use.

At the National Physical Laboratory the model is suspended about some fixed axis, and readings are taken at various angles of incidence of the chord, of Lift, Drift, and moment about the axis, the resultant being thus fixed by method (2). Since, however, the position of this axis is chosen solely from reasons of experimental convenience and is not a position of any interest to the designer of full-sized machines, the results when obtained are reduced either to the form Lift and Drift, and moment about an axis in the leading edge of the aerofoil, or in other cases to the form Lift, Drift and position of the centre of pressure on the chord, as previously defined. Practically all the laboratories show, either by means of plotting or by tables, the variation of these different quantities with angle of incidence at some fixed wind speed, and it is a common practice to replace the curve of drift by one of the ratio of lift to drift, since this curve is one of great interest to the designer. Figs. II., III., IV. show typical curves of these quantities for a good aerofoil.

It will be noticed in Fig. IV. that as the angle of incidence decreases through —3° the centre of pressure disappears to infinity behind the plane and reappears again from infinity in front. At first sight this may seem somewhat alarming, but in reality it only means that the magnitude of the resolved part of the force normal to the chord vanishes whilst there is still a finite couple acting on the aerofoil, so that the distance of the centre of pressure, which is equal to the couple divided by this force, becomes infinite although the magnitude of the couple itself may be quite small. The curve of centre of pressure therefore becomes practically useless and even misleading in this neighbourhood, and it is for this reason, and also for convenience in arithmetical calculation, that the curve of moment about the leading edge is often included, although strictly speaking it is not necessary when the centre of pressure curve is given.

The other method of giving the direction and position of the resultant graphically is occasionally adopted, but usually for a special purpose, or because it is specially asked for by those for whom the experiments are performed. One convenient method of graphical representation is to draw in the envelope to the resultants for various angles of incidence, this curve together with the lift and drift curves being sufficient for the purpose, since the lift and drift curves fix the direction of the resultant and a tangent drawn to the curve parallel to this direction gives its position.

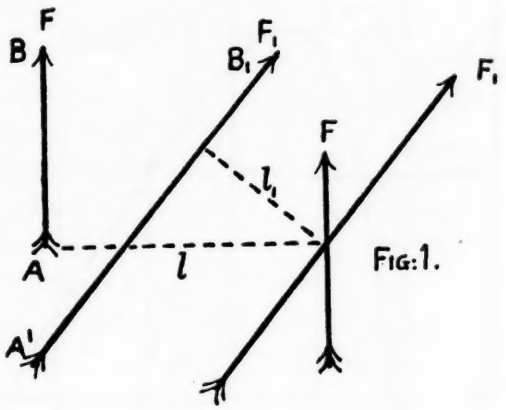
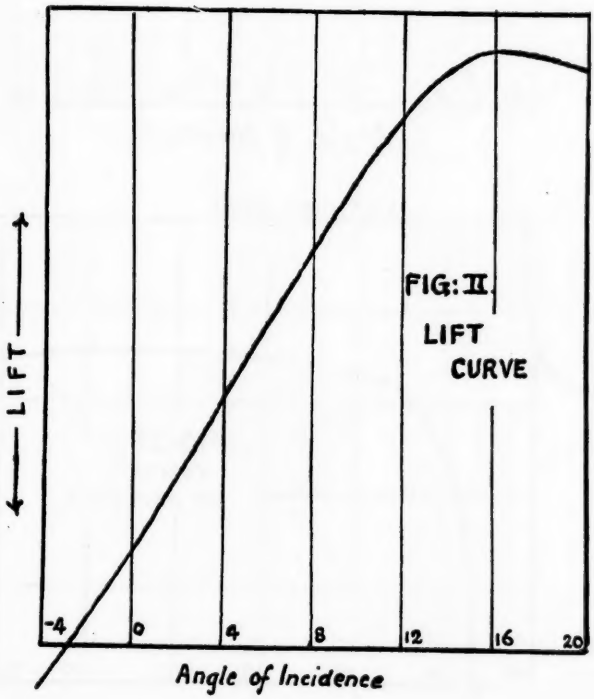

F
B
F1
B1
F1
F
l1
A
l
A'

FIG: 1.


LIFT
FIG: II.
LIFT
CURVE
-4
0
4
8
12
16
20
Angle of Incidence

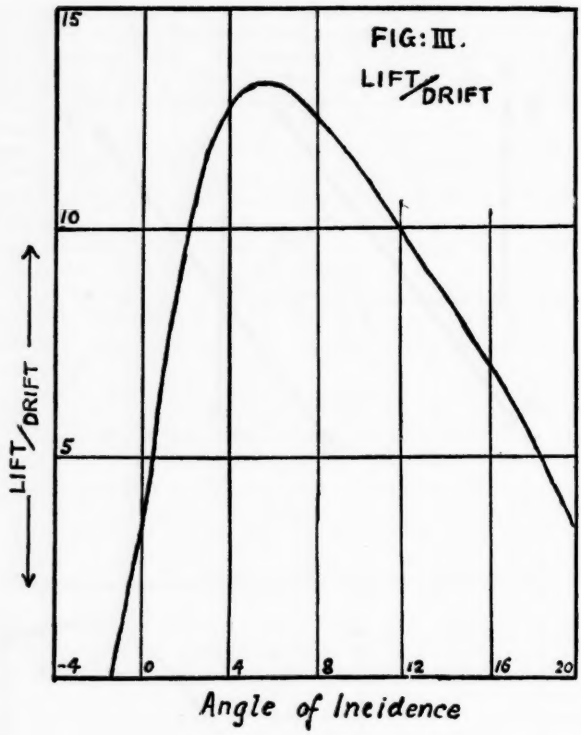
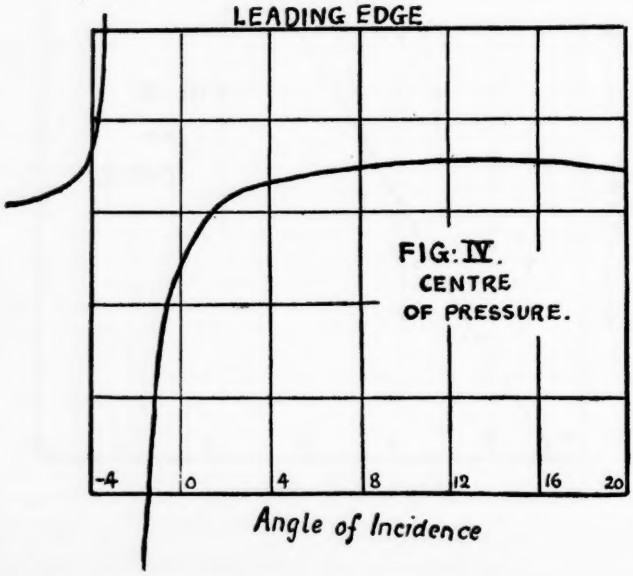


FIG: III.
LIFT/DRIFT
15
10
5
LIFT/DRIFT
-4
0
4
8
12
16
20
Angle of Incidence


LEADING EDGE
FIG: IV.
CENTRE
OF PRESSURE.
-4
0
4
8
12
16
20
Angle of Incidence

At the Laboratory conducted by M. Eiffel, at the Champ-de-Mars, there are two distinct methods by which the line of action of the resultant can be determined. The one method, which is that most generally adopted, is to pivot the model freely about various axes normal to the plane of symmetry and to note the angle of incidence taken up when the wind is turned on, the resultant force upon the model then passes through this axis at the observed angle of incidence. The lift and drift upon the model is determined in a separate experiment, and since this implies a knowledge of the direction of the resultant, the line of action is completely determined.

The other method by which the line of action can be fixed occurs incidentally during the measurement of lift and drift, but is not considered to determine the line of action sufficiently accurately, and is therefore seldom used; in effect it consists of pivoting the model about three different axes in turn and observing the moment about each; in this way three different quantities are known about the resultant, and consequently its magnitude and line of action are completely determined.

For purposes of publication M. Eiffel converts his results, however obtained, to the form Lift, Drift, and Centre of Pressure.

It will be noticed that when using the method of pivoting freely about a single point, it is necessary to know the direction of the resultant before its line of action can be determined, and consequently unless the direction is known from a separate experiment the observations will be practically valueless. If it is desired to find the line of action of the resultant without determining its magnitude, it is necessary to pivot the plane about two different points at which it takes up the same angle of incidence. This method has been employed by Mr. A. P. Thurston, of the East London College; his procedure was to pivot the plane about a series of points along two parallel lines, one being the chord, and the other the tangent to the upper surface parallel to the chord. Curves were then drawn, showing the position of the point of balance, in each case, plotted against the corresponding angle of incidence and, from these, pairs of points, corresponding to the same angle of incidence, on two parallel lines, could be found by interpolation, and thus the position of the resultant fixed without any measurement of force having been necessary.

NOTES

Fatalities. The list of fatalities grows no smaller. That following is believed to be as complete and accurate as possible. While the larger number of deaths occurred amongst those with only slight experience in flying, the names of some experienced pilots will be noticed.

For example, Mr. H. J. D. Astley who, though only 24 years old, had a remarkable aviation record, was killed at Belfast on the 24th September. The cause of the accident was a sideslip on an overbanked turn, which was accentuated by the aviator's heroic and successful attempt to clear the crowd. The actual fall was only about 30 or 40 feet, but as he was without belt or helmet he sustained serious injuries, from which he succumbed within a few hours.

Astley took his pilot's certificate on December 31st, 1910 (Sommer biplane, Brooklands). He flew a Bleriot-type monoplane, built by the Universal Aviation Company, Limited, in the Circuit of Britain, but engine troubles discounted his otherwise fine performance. At the end of August he crossed the Channel with Miss Trehawke Davies, *en route* from London to Paris. On this continental trip both he and his passenger had a remarkable escape.

Although the actual tests of the Military Trials were carried through without any fatality, Mr. R. C. Fenwick, who had entered the Mersey monoplane of his own designing and building, unfortunately sustained an accident on Tuesday evening, August 13th. It is believed that a sudden gust was responsible for overturning the machine when at a height of about 300 feet. The Mersey monoplane was remarkable for its short length and the fact that the propeller was at the tail of the fuselage—an unusual feature in monoplanes. Mr. Fenwick was a designer of originality and promise, which unhappily will now not be fulfilled.

The Royal Flying Corps was particularly unfortunate in September; no less than four of its members being killed in two accidents. The first was on September 6th. Capt. Patrick Hamilton of the Worcester Regiment with Second Lieut. A. Wyness-Stuart was flying the Army Trials 100 H.P. Deperdussin monoplane at about 7 o'clock in the morning over Graveley, near Hitchin. Suddenly the machine swayed violently and almost immediately after fell to the ground.

The second accident occurred on September 10th. Lieut. E. H. Hotchkiss with Lieut. C. A. Bettington as observer was flying a Bristol monoplane from Salisbury Plain to the Army manœuvres. When over Wolverton, near Oxford, at a height of about 200 feet, one of the wing-stay attachments failed and the machine fell like a stone.

These two accidents created a lasting impression, originating, as they did, in some constructional defect.

The first aviator to be killed in war was a scout of the Bulgarian Army, who was brought down by gun fire whilst making a reconnaissance at Adrianople. He was Lieut. A. Popoff (a Russian) flying a Wright biplane. This incident does not, however, throw much light upon the question of aerial reconnaissance, as it is understood that Popoff did not take proper precautions to avoid being hit.

Miss Quimby's Accident. With regard to Miss Quimby's accident a rather acrimonious discussion has taken place, the theory put forward by E. L. Ovington, mentioned in our last number, having been strongly controverted and gyroscopic force made responsible for the accident, by Mr. T. Preston Brooke who has, as is well-known, invented a non-gyroscopic motor. The importance of the question demands that experimental investigation should be undertaken as soon as possible with a view to discovering the limit of the gyroscopic action of revolving motors and propellers.

The Akron Disaster. An exhaustive inquiry into this disaster was made by the Goodyear Tire and Rubber Company, and in the result they discount the theory of the failure of the fabric and consider that either breakage of the suspension ropes or of the propeller was the real cause of the disaster.

Public Safety and Accidents Committee. The widespread desire that some accredited body should investigate accidents led early in the year to the Royal Aero Club, as affiliated to the F.A.I., constituting the above Committee. The Society's representatives on it are:—Mr. A. E. Berriman, Mr. J. H. Ledeboer, and Mr. Mervyn O'Gorman. Major-General R. M. Ruck, the Chairman of Council, is also on the Committee in a personal capacity.

Several valuable reports have been made by this Committee, and, with a view to obtaining necessary data in regard to certain "dives" by aeroplanes, the co-operation and assistance of the Advisory Committee for Aeronautics is being sought in order that experiments may be carried out at the National Physical Laboratory on the subject.

Royal Flying Corps. A notable step forward was taken in the organisation of national aviation by the foundation of the Royal Flying Corps. The initiation of this Corps was announced in a War Office Memorandum (Cd. 6067) of the 11th April, 1912. Briefly, the national aeronautical service is to be regarded as one, with a naval and military wing administered by and at the expense of the Admiralty and the War Office respectively. The headquarters of the naval wing are at Eastchurch, and those of the military wing at Farnborough. The future of the Corps is, at present, difficult to forcast, but already the fusion of naval and military interests has proved so successful that it is to be hoped they will not be separated hereafter.

Military Aeroplane Trials. When, on the 16th May, the War Office issued a notice to competitors respecting the Military Aeroplane Competition, and stated that entries must be received before the 15th June, 1912, it was thought that much too little time had been allowed for preparation. As events turned out, however, the trials were admirably carried out and the results surprisingly little open to objection. The prizes were divided into two classes:—

(A) Open to the world for aeroplanes made in any country. First prize, £4,000; Second, £2,000.

(B) Open to British subjects for aeroplanes manufactured wholly in the United Kingdom except the engine. First prize, £1,500; two second prizes, £1,000 each; three third prizes, £500.

The trials actually commenced as from August 1st on an aviation ground of about ten square miles on Salisbury Plain. The judges were:—

Brigadier-General D. Henderson, C.B., D.S.O., Director of Military Training War Office.
Captain Godfrey M. Paine, M.V.O., Commandant of the Central Flying School.
Mr. Mervyn O'Gorman, Superintendent of the Royal Aircraft Factory.
Major F. H. Sykes, Officer Commanding, Military Wing, Royal Flying Corps (Secretary).

The weather during the Trials was, in the words of the Official Report, "persistently unfavourable" and most of the flying was done under the most trying conditions.

The order of merit obtained was as follows:—

1. Cody biplane (British), No. 31.
2. Deperdussin monoplane (French), No. 26.
3. { Hanriot monoplane (French), No. 1 / Maurice Farman biplane (French), No. 22 } Equal.
5. { Bleriot tandem monoplane (French), No. 4 / Hanriot monoplane (French), No. 2 } Equal.
7. { Deperdussin monoplane (British), No. 21 / Bristol monoplane (British), No. 14 / Bristol monoplane (British), No. 15 } Equal.
10. Bleriot "Sociable" monoplane (French), No. 5.

It will be seen that ten machines were considered worthy of being placed in the above list. (Thirty-two entries were received and 25 aeroplanes were delivered on the ground.) The success of the Cody machine was extremely popular and may be justly claimed as an endorsement of the faith of the Society in the member to whom, in 1909, it awarded its silver medal.

Perhaps the most important conclusion to be drawn from the Trials is that we have in England, at present, no aeroplane-engine industry approaching that of France. It is essential for national security that this state of affairs should be remedied without delay.

Strength of Monoplanes. Monoplanes have recently been under a cloud. The first premonition of this was a report in March by Mons. Bleriot to the French Government on the possibility of negative pressure on the wings existing during sudden downward turns. This report undoubtedly called attention to a source of danger which had hitherto not received much notice. The fact that many monoplanes have failed constructionally during the year has caused somewhat of a reaction in favour of the biplane, which had previously appeared to be rather outstripped in the race for favour by the monoplane. There is no reason, however, why increased attention to scientific design and construction should not make the monoplane as reliable as the biplane.

1912 Gordon-Bennett Aviation Cup Race. This contest took place on September 9th at a specially prepared oblong aerodrome of 4·142 miles to a lap, near Chicago. The highest speed was obtained by Védrines, who covered 20 kilometres in 6 minutes, 55·95 seconds, establishing a new world speed record. The contest was confined to three French competitors only, Védrines, Prevost, and Frey. Although it showed that in fine weather aeroplanes can be made to fly at over 100 miles per hour round a very small ellipse, it cannot be said that the information acquired is at all commensurate with the very great expense involved.

It does not seem that this type of race ever will give results which are worth the getting, and it is to be hoped that, in future, contests will be of the cross-country type.

The Future of Aviation. The notes under this heading in the corresponding issue of a year ago have proved to be singularly accurate in their forecast of possible development.

The hydro-aeroplane has developed rapidly, but is still, in most cases, what its name implies, a hybrid or mongrel affair. The designing of a machine which shall be something more than an aeroplane with hydroplane attachments is a matter of extreme difficulty, the varying needs of air and water transit being so difficult to meet in one apparatus.

The need for perfecting automatic stability devices is now generally recognised and progress should be rapid.

The career of the dirigible during the year has been somewhat fluctuating, apparent successes being interspersed with crushing disasters. It is now realised that to do justice to dirigibles they must be equipped with much greater power than has, at present, been the case. It seems possible that adequately-powered dirigibles with efficient steering apparatus have a distinct future.

The progress of cross-country flying has been rapid, and the need for the framing of an aerial law code has become correspondingly more apparent. The effect on the future of flying of the proper drawing-up of such a code is of such overwhelming importance that too much attention cannot be paid to it in the immediate future.

LIST OF FATALITIES

Date. 1912		Name.	Nationality.	Machine.	Place.
July	17 ..	Lieut. Zakutzky	Russian	——	Sebastopol
July	30 ..	Sergt. Lachmann	German	——	Doeberitz
Aug.	3 ..	C. Lindsay-Campbell	Australian	Bristol (1)	Byfleet, nr. Brooklands
Aug.	13 ..	R. C. Fenwick	English	Mersey (1)	Larkhill, Salisbury Plain
Aug.	25 ..	Lieut. Manzini	Italian	——(1)	Drowned at sea, nr. Tripoli
Aug.	25 ..	Fung Pue	Chinese	——(2)	Canton
Aug.	28 ..	Lieut. Chandenier	French	(2)	Crecy-sur-Serre (Aisne)
Sept.	6 ..	Lieut. Otto Steger	Bavarian	Otto (2)	Nr. Munich
Sept.	6 ..	Capt. P. Hamilton Lieut. A. Wyness-Stuart (P)	English	Deperdussin (1)	Graveley, nr. Hitchin
Sept.	10 ..	Lieut. E. H. Hotchkiss Lieut. C. A. Bettington	English S. African	Bristol (1)	Oxford
Sept.	11† ..	W. B. Chambers	American	Bristol (2)	Greene (N.Y.)
Sept.	11 ..	— Stauwater	German	Jeannin (1)	Johannistal
Sept.	11 ..	M. Karamanlakis	Greek	Bleriot (1)	At sea, Corinth
Sept.	11 ..	Paul Peck	American	Columbia (2)	Chicago (Ill.)
Sept.	11 ..	Lieut. Siebert	German	——	Dresden
Sept.	14 ..	Howard Gill	American	Wright (2)	Chicago (Ill.)
Sept.	14‡ ..	M. Borie (P.)	French	Farman Hydro (2)	Weert
Sept.	15 ..	Lieut. Aldo Inghetti	Italian	Inghetti	Lanciano, nr. Chieti
Sept.	15 ..	Lieut. Bongiovanni	Italian	Bleriot (1)	Nr. Beaux
Sept.	20 ..	Russell Blair	American	——(2)	Shenandoah (Iowa)
Sept.	20 ..	George Underwood	American	Curtiss (2)	Calao (Mo.)
Sept.	22 ..	H. J. D. Astley	English	Bleriot (1)	Belfast
Sept.	22 ..	Lieut Berger Lieut. Junghaus	German	Albatros (2)	Nr. Chemnitz
Sept.	24 ..	Lieut. Thomas	French	——(2)	Givronval
Sept.	25 ..	Lieut. Ragazzoni	Italian	Chiribiri (1)	Mirafiore (Rome)
Sept.	25 ..	Capt. G. L. Bumbaugh	American	——(2)	N. Manchester (Ind.)
Sept.	28 ..	J. Longstaff	English	Farman (2)	Hempstead (Long I.)
Sept.	28 ..	Lieut. L. Rockwell Corpl. F. Scott (P.)	American	Wright (2)	Washington
Sept.	30 ..	Lieut. Hefer	German	——	Tannenberg
Oct.	3 ..	Chas. Walsh	American	Curtiss (2)	Trenton (New Jersey)
Oct.	4 ..	Ernst Alig — Liebau (P.)	German	Kühlstein (1)	Johannistal

† Date of death. Accident, 6th Sept.
‡ Date of death. Accident, 10th Sept.
(P.) Passenger. (1) Monoplane. (2) Biplane.

Date. 1912.		Name.	Nationality.	Machine.	Place.
Oct.	4 ..	Aug. Berkmaier	German	Schulze-Herfort (2)	Vahrenwald (nr. Hanover)
Oct.	6 ..	Yolig M. Monteur (P.)	German French	(1)	Johannistal
Oct.	6 ..	Motohisa Kondo	Japanese	Kirkham (2)	Savona (N.Y.)
Oct.	7 ..	S. Piccoli (P.)	Italian		Rome
Oct.	8 ..	J. Stevenson	American	Curtiss-type (2)	Birmingham (Ala.)
Oct.	8 ..	Lieut. Sarakoff	Bulgarian	Albatros (2)	Johannistal
Oct.	10 ..	M. Rajewski	Russian	Rajewski (2)	St. Petersburg
Oct.	14 ..	Alex. Takacs	Hungarian	Kolbanyi	Rakos
Oct.	15 ..	M. Cobioni M. Bippert	Swiss	——	La Chaux de Fonds
Oct.	17 ..	M. Blanc	Swiss	Antoinette (1)	Châlons
Oct.	19 ..	Lieut. Deissbarth Lieut. Lange	Bavarian	Euler (2)	Giengem-am-Brenz
Oct.	20 ..	A. Lacour	French	(1)	Mussidan
Oct.	23 ..	L. Mitchell	American	Wright (2)	Montgomery (Ala.)
Oct.	30 ..	Lieut. Moritz Hamburger	German	Otto (2)	Oberwiesenfeld (Munich)
Oct.	30 ..	Lieut. A. Popof	Russian	Wright (2)	Adrianople
Oct.	31* ..	Lieut. Poutrin	French		Laon
Nov.	5 ..	Sub-Lieut. Marechal	French	(2)	Houville
Nov.	5 ..	Lieut. Petrovics	Austrian	Etrich (1)	Gorice (Carniola)
Nov.	6 ..	Lieut. Altrichter Eng. Meyer	German	Bristol (2)	Halberstadt (Saxony)
Nov.	21 ..	M. J. Laurent	French		Etampes
Nov.	21 ..	André Frey	French	Hanriot (1)	Reims

* Date of death. Accident, 18th October.

(P.) Passenger. (1) Monoplane. (2) Biplane.

NEW BOOKS AND PUBLICATIONS

* Modèles d'Aéroplanes. Adrien Fieux. Paris: Librairie Aeronautique. 1912. pp. 127. Illus. 2 francs.

Les Moteurs à deux temps. L. Ventou-Duclaux. Paris: H. Dunod et E. Pinat. 1912. pp. 127. Figs. 4 francs 50.

*Apprécier un Aéroplane L'améliorer s'il y a lieu. Capitaine du Génie Duchêne. Paris: Librairie Aeronautique. 1912. pp. 58. Figs. 1 franc 50.

Comment servir dans l'Aeronautique Militaire. G. le Grand. Preface by General Roques. Paris: Librairie Militaire Chapelot. 1912. pp. 62.

Aviation. Sydney F. Walker. London and Edinburgh: T. C. and E. C. Jack. 1912. pp. 96. Illus. 6d. n.

Das Flugzeug in Heer und Marine. Olszewski und Helmrich v. Elgott. Berlin: Richard Carl Schmidt and Co. 1912. pp. 288. Illus. M. 7.

*Analysis of the British Military Aeroplane Trials, 1912. A. E. Berriman. London: "Flight." 1912. pp. 18. 6d. n.

Magneto and Electric Ignition. W. Hibbert. London: Whittaker and Co. 1912. pp. 154. Figs. 2s. n.

Military Aeroplane Competition, 1912. Report of Judges Committee. London: Wyman and Sons. 1912. pp. 22. 1s. 2½d. n.

Seventh Annual Report of the Meteorological Committee. London: Wyman and Sons. 1912. pp. 173. Illus. 1s. 7d. n.

Technical Report of the Advisory Committee on Aeronautics, 1911-12. Wyman and Sons. 1912 pp. 323. Illus. 11s. n.

* Essais d'Aerodynamique. (Part II.) Armand de Gramont. Paris: Hachette and Co. 1912. pp. 108. Illus.

Cours d'Aeronautique. (Part III.) L. Marchis. Paris: H. Dunod et E. Pinat. 1912. pp. 279. Illus. 12 francs.

The Boys' Book of Aeroplanes. T. O'Brien Hubbard and C. C. Turner. London: Grant Richards, Ltd. 1912. pp. 227. Illus. 6s. n.

* Die deutsche Patente über Flugapparate. Dr. B. Alexander Katz. Berlin: M. Krayn. 1912. pp. 723. Illus. 25 M.

Airships and Aeroplanes. M. O'Gorman. 1912.

Sovreignty over the Air. Sir H. Erle Richards. Oxford: Clarendon Press. pp. 27. 1s. 6d. n. (A notice of this book will appear in the next issue of the Journal.)

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* Review appears in this issue.

REVIEWS

Analysis of the British Military Aeroplane Trials, 1912. By A. E. Berriman, A.F.Aë.S. (London: "Flight," 1912, pp. 18.)

FROM the point of view of the outsider it is no doubt very interesting to take the simple figures of weight per square foot and weight carried per horse power and attempt to obtain a value for the velocity of flight, but the formula that Mr. Berriman has given by no means fulfils the condition of giving the absolute best value for the speed as the constant k in the formula $X = kV$ varies considerably with varying machines.

Let us consider a little more closely what this coefficient X means. The load per horse power is equal to the $\frac{\text{Pressure on planes,}}{\text{H.P.}}$. The horse power required for horizontal flight is equal to

$$\frac{\text{Pressure on planes} \times \text{tangent of gliding angle} \times \text{velocity m.p.h.}}{375}$$

The load per horse power is, therefore:—

$$\frac{\text{Pressure on planes} \times 375}{\text{Pressure} \times \text{tan. gliding angle} \times \text{Velocity.}}$$

This reduces to

$$W_1 = \frac{375}{\text{tan. (gliding angle)} \times \text{Velocity.}}$$

Load per square foot is equal to

$$W_2 = \frac{\text{Pressure on planes}}{\text{plane area.}}$$

It follows, therefore, that

$$W_1 \times W_2 = \frac{375 \times \text{Pressure on plane}}{\text{tan. (gliding angle)} \times \text{Velocity} \times \text{plane area.}}$$

The pressure on the plane may be calculated from the formula—

$$P = S \frac{w}{g} AV^2\theta.$$

where P = pressure, S = sweep factor, w = density of the air, G = acceleration due to gravity, A = plane area, V = velocity, θ = angle through which the air is deflected. This formula has already been explained in a paper read before the Aëronautical Society.* Substituting this value in the above formula—

$$W_1 \times W_2 = \frac{375 \times S \times \frac{w}{g} \times AV^2\theta}{\text{tan. (gliding angle)} \times V \times A}$$

or

$$W_1 \times W_2 = \frac{375 \times S \times \frac{w}{g} \times V \times \theta}{\text{tan. (gliding angle)}}$$

$$= \left(\frac{375 \times S \times \frac{w}{g} \times \theta}{\text{tan. (gliding angle)}} \right) \times V$$

If we assume that S = 1, $\theta = 18°$ or .31 radians,

$$W_1 \times W_2 = 1.75.$$

* "The Pressures on Planes and Curved Surfaces moving through the Air."—AËRONAUTICAL JOURNAL, April, 1911.

The assumption that the value is always about 2 is quite incorrect, as it depends entirely on what the values of the angle of deflection of the air and of the gliding angle are. It must be noted too that this value for the velocity is only true so long as the correct H.P. value is given *for horizontal flying only*.

With the data given it would be far and away easier to calculate the velocity at the start from the formula—

$$V = \frac{\text{H.P.} \times 375}{\text{Plane pressure} \times \tan.\text{(gliding angle)}}$$

This formula being thus only an approximation the value of ϵ does not convey much.

The tables and the charts are very interesting, but as they are only approximations they do not convey much meaning.—F. H. P.

Die deutschen Patente ueber Flugapparate. By Dr. B. Alexander Katz. (Berlin: M. Krayn, 1912. pp. 732. Illus. 25 marks.)

THIS work is a complete collection of the German patents relating to Flying Machines from 1879—June, 1911.

Dr. Alexander Katz merits for his industry the thanks of all persons seriously interested in Aeronautics. A man who devotes time and thought to making knowledge readily accessible renders excellent service to his fellow-students and through them to the world at large.

This work, however, may prove of interest rather to the scientific historian than to the present-day constructor, especially as regards the aeroplane maker. German official investigation into patent applications is well known to be extremely searching. This commendable thoroughness is unfortunately associated with delay in publishing approved specifications. Hence, although the present volume contains specifications *issued* as late as June, 1911—fifteen months ago—such patents have been granted on subject matter in applications lodged many months before June, 1911; so that out of the 299 specifications contained in the book, only two or three relate to improvements for which protection was asked as recently as the *first months of* 1910, *i.e.*, at a time when German experience in actual construction of aeroplanes was *nil*.

The method of compilation is chronological order in subject group divisions. Index of names of inventors, and a comprehensively classified list of the subject of the patents, enable a searcher readily to locate all patents bearing on the points in which he is interested.

Naturally, this volume contains particulars of some patents which will always be of historical interest; but such are not necessarily due to Teutonic ingenuity. One of the most interesting from every point of view is that of the Wright glider. Sir Hiram Maxim's patent, protected in 1891, recalls his strenuous efforts to construct a "heavier than air" machine. French genius and enterprise are represented by Blériot, Clément, Esnault-Pelterie, and others.

Supplementary volumes, which one hopes will be issued more promptly, will undoubtedly contain a far larger proportion of patents utilisable in current construction; but all aeronautical libraries should acquire a copy of the present issue.

This volume, which to most men would seem as arid and utilitarian in contents as Bradshaw's Guide, will to a happily equipped few be packed with interest. These will appreciate the mechanical poems and shudder at the balderdash; but the permanent appeal will be to the sense of human comradeship. The dry descriptions of apparatus and processes often represent the results of years of patient thought and personal sacrifice for the common good; courageous, ingenious, and persistent battle against hosts of difficulties which we others have failed to assail. Alas, too often, when the position is carried, the victor realises that he has exhausted himself in an outpost affray which has no bearing on the main issue.

J. E. H.

Luftschrauben. Leitfaden fuer den Bau und die Behandlung von Propellern. By Paul Béjeuhr. (Frankfort: F. B. Auffarth, 1912. pp. 180. Illus. 4 marks.)

IN this treatise the principal theories affecting propeller design have been brought together in their logical relationships. Methods of calculation derived from the diverse theories are exhaustively illustrated through the detailed working out of elementary examples. The author has endeavoured to accustom his reader to separate essentials that are valid for all propeller theories from the particular considerations that affect only special cases, and thus hopes to render his work of significance and value also for theories which may yet be formulated.

The work is of significance, both for those interested in balloons, and also for the larger number (in this country) devoted to aeroplane construction.

Calculations and formulæ are to be found in abundance, and the work of Wellner, Ferber, Camus, Drzewiecki, Eberhardt, Lanchester and others is discussed. Formulæ to determine the comparative worth of propellers based on coefficients suggested by Prof. Prandtl, Göttingen, receive consideration. Points dealt with include experimental research, bench experiments, tests on propellers mounted on moving apparatus, whirling arms, test cars, &c. Full description of apparatus is generally given, and there are 90 illustrations and graphs.

There is a pretty full section devoted to the production of propellers, materials used, wooden propellers, metal propellers, methods of mounting, maintenance, practical precautions.

The whole book bears the impress of thorough and conscientious work, but some of the worked out examples might have been better displayed. One does not like to see calculations jumbled up with the text, thus forcing advanced mathematicians to read every small step necessary for the instruction of the tyro.

Where discussing the best kinds of timber to use, American walnut is rightly given a place of honour. Kauri pine, however, is not, as stated by the author, amerikanisches Tannenholz, but is a New Zealand wood, and further, is *not* to be recommended for propellers. A more serious mistake is made in identifying Italian walnut as *satin* walnut, and then condemning the former for the sins of the latter. Italian walnut is actually the best wood for propeller making, but is five times as costly as "satin" walnut, which is really American gum. One troubles to point out errors of this sort, for the selection of proper materials is, at the present stage, perhaps, more important than the choice of competing theories in design.

J. E. H.

Modeles d'Aeroplanes : leur construction. By Adrien Fieux. (Paris : Librairie Aeronautique, 1912. pp. 127. Illus. 2 francs.)

We can recommend this little book of 130 pages with confidence to the English model-maker, who will find within its pages many welcome fresh ideas in the matter of design and detail.

It can hardly be called "right up-to-date," as it only deals with the construction of models of simple form driven by rubber. There is no mention of power-models, hydro-aeroplanes, and the like.

Besides that part devoted to model construction, there is another portion of this little book which will be read with the greatest interest by all who study aeronautics : that is those first 100 pages, devoted to the early history of the subject, where will be found a very complete list of early experimenters with a short description of each, and of his apparatus. Among such pioneers is, of course, Sir George Cayley, whom we Englishmen have quite rightly looked upon almost as the father of modern aeronautical science ; it was, however, something of a shock to the writer to read that one of his prettiest inventions, namely, his toy hélicoptère, was invented in 1784, twelve years earlier, by two Frenchmen, Launoy and Bienvenu.

The author is well advised in giving separate descriptions of this and certain of the more famous of the classic models.

Finally, we would say that we hope the young constructor who makes use of this book will no more take the machine represented on the cover as a type to be copied, wanting as it is in curvature, stability and perspective, than employ the methods of the elder model maker, who is shown using a heavy plater's hammer—the lightest tap from which might be guaranteed to put out of action the most substantial model.

T. W. K. C.

The Dynamics of Mechanical Flight. Lectures delivered at the Imperial College, March, 1910 and 1911. By Sir G. Greenhill. (London : Constable and Co., Ltd. 1912. Price 8s. 6d. net.)

Up to the present time a noticeable feature of aeronautical work has been the want of a clear understanding as to the exact part which should be played by mathematical calculations in investigating the properties of aeroplanes and airships. This is the more surprising in view of the experience previously gained in the development of electricity. The study of aeronautics has hitherto failed to attract many of our best mathematicians, and there are probably greater inducements for them to engage in electrical researches. On the other hand, papers are often written by practical men containing elaborate usages of algebraic formulæ, sometimes strung together with an utter disregard for the fundamental principles of elementary mathematics and physics. The consequence is

that results are believed to be proved mathematically when it should be evident from the nature of the case that they do not admit of mathematical proof, and that the only evidence as to whether they are true or false must be derived from actual experiments.

In view of the chaotic conditions that have thus arisen a very useful purpose will be served by the publication of a book under the authorship of so reliable a mathematical authority as Sir George Greenhill. What was most wanted, and what we here have is an exposition of the principles and formulæ of statics, dynamics, hydrodynamics, and applied mathematics in general. that are applicable to the calculation of the forces acting on aeroplanes and airships. Although the book is based on a course of lectures delivered at the Imperial College, London, it is fairly comprehensive in regard to essential points, though of course the subject could be enlarged indefinitely and a big book written which, however, would probably be less useful to the large class of readers whose time is limited. The subjects treated include general principles of flight, lift and drift, calculations of thrust and centre of pressure, the theory of discontinuous fluid motion, gyroscopic action, the screw propeller, and the pneumatical principles of an airship.

The introduction is characteristically Greenhillian and deals with references to Demeter and Homer, Aeschylus, Alexander the Great, Chaucer, Dr. Johnson, the pterodactyle, Pope, Santos Dumont, and Roger Bacon. It contains an illustration from a British Museum manuscript.

The pressure of a fluid moving past a plane barrier, and its application to calculations of the lift and drift of an aeroplane form the subject of the first three chapters. It is probably in connection with this particular class of calculations that the most serious misunderstandings have arisen regarding what can and what cannot be done by mathematical analysis, and a digression on this point may not be out of place in this review.

In the first place it should be clearly understood that the actual thrust on an actual aeroplane moving in a given manner is a quantity that can only be determined by actual experiments performed either with full-sized planes or models of them. A mathematical investigation (commonly called a "theory") is really an experiment performed with integration formulæ, methods of solving partial differential equations and other apparatus of like character on an assumed surface moving in an assumed medium, these being so chosen as to enable the experiment to be performed with the apparatus that are available. The result usually assumes the form of a law or formula, and a comparison of the two methods enables us to establish laws either exact or approximate, governing the pressures on planes, to explain why and how these pressures are produced, and finally to replace what would otherwise be a bulky table of statistical data by working rules and formulæ.

Now there have been two methods of building up a mathematical theory of pressures in a fluid medium. The first is due to Newton, who assumed that the pressure on a plane could be measured by the change of momentum produced in the particles of the medium with which it came in contact. This led to the result stated by Newton that "in media which are devoid of all rigidity the resistances of all bodies are in the duplicate ratio of the velocities" (see Greenhill, page 14); and it further led to the so-called sine squared law which does not agree with the results of observations on aeroplanes gliding at small angles. It is, however, a rigorous deduction from the assumed hypothesis. The conclusion to be drawn from its failure is that it is necessary to treat the air as a continuous medium, and to investigate the stream lines in the neighbourhood of a plane instead of measuring the pressure by the momentum generated in a limited column of the medium.

Yet in spite of this, the Newtonian method still finds favour with "practical men." Mr. A. E. Berriman has in published papers tried to apply it to cambered planes, and in order to do so he makes assumptions that are contrary to the fundamental principles of elementary mechanics and physics. In the first place, he assumed that the pressure is measured by the momentum communicated to a certain column of air, the depth of which is called the "sweep," and in the second he assumes that the change of velocity of this column is given by a tangent formula which for a cambered plane he sometimes gives as the tangent of the difference and sometimes as the difference of the tangents of the inclinations of the front and rear edges. Mr. Berriman has not been very particular about which he used.

Now, in the first place there is no such thing as "sweep" except in Newton's ideal medium of non-interfering particles satisfying the sine squared law. In a fluid medium the disturbance produced by a moving solid theoretically extends to an infinite distance, gradually decreasing as we go further off. Mr. Berriman's "sweep" is, physically speaking, an impossibility. If, however, "sweep" is defined as the depth of a hypothetical column of air, the change of momentum in which would represent the pressure on the plane, then the introduction of this new quantity is only a useless and unnecessary complication. Instead of facilitating the determination of the unknown data of the problem, it merely replaces one variable which is physically intelligible and capable of experimental determination by another variable satisfying neither of these conditions.

A further objection to this Neo-Newtonian-Berriman method is the assumption of the tangent formula forthe deflection in place of a more plausible hypothesis such as the sine formula. It is difficult to see how a tangent formula can be justified from any elementary physical considerations except on the impossible hypothesis that the aeroplane possesses negative skin friction tending to accelerate and not retard the portions of the medium coming into contact with it. Even a perfectly smooth surface only produces a deflection proportional to the sine of the angle of attack.

The second method involves the solution of problems in discontinuous fluid motion. The fullest discussion of this method is contained in Sir George Greenhill's report on the subject to the Government Committee* ; in the present book he considers only the simpler cases, suitable for the study of candidates who have attained the standard of B.Sc. honours in mathematics and physics.

The fundamental features of this method may be summed up as follows:—

(1) The relation between pressure and velocity at different points of a stream line is given by Bernouilli's equation.

(2) Where the stream lines leave the edges of the plane, there is a discontinuous difference of velocity accompanied by no corresponding discontinuity of the pressure.

If the stream line motion past an actual aeroplane could be studied experimentally it is pretty certain that the pressure on the plane could be calculated from Bernouilli's formula, and that no serious discrepancy would exist between the results of calculation and observation.

But when we come to determine the stream line motion by experiments made with the aid of our existing mathematical apparatus, we require to assume—

(1) That the fluid medium is incompressible and devoid of viscosity.

(2) That the motion is two dimensional—a condition satisfied near the middle of an aeroplane of considerable span, but not in close proximity to the ends of the plane.

(3) That the stream line motion does not break up into eddies soon after leaving the surface.

In spite of these shortcomings the theory of discontinuous motion affords the best opening to the study of pressures on planes from the mathematical standpoint. It has engaged the attention of the following mathematicians, among others:—Holmholtz, Kirchhoff, Schwarz, and Christoffel, Michell, Lord Rayleigh, Love, and finally Greenhill himself, who has in his report greatly simplified the methods of treatment besides classifying the cases which admit of simple solution. These cases include, besides the problems suggested by aeroplanes, other investigations referring to fluid jets issuing from orifices in polygonal vessels, of a very general character.

The application of these methods to bent and cambered planes has not hitherto been developed to any considerable extent. On page 40 of the present volume, one such development is suggested, although it is pointed out that the integrations become "intractable." But it appeared to the present reviewer that these difficulties did not prevent Greenhill's methods from being applied to determinations of lift and drift. Some calculations of this kind are now being undertaken at Bangor by Mr. Robert Jones, who, it may be interesting to observe, is probably the first candidate who has taken a University examination paper on the subject of "Aeroplane Stability."

In a "Digression on the Integral Calculus" Greenhill discusses the formulæ required for the first integrations in problems involving *two* discontinuous stream lines, or problems reducible to these by principles of symmetry. Where more than two discontinuous stream lines are involved the first integrations introduce elliptic integrals.

The chapter on gyrostatic action is very important owing to the great effect which this has on the steering of aeroplanes. Attention should be drawn to the importance of balancing and neutralising this action by combinations of rotating parts revolving in opposite directions. This chapter will be found easy reading, and Greenhill's experiments with bicycle wheels and tops will afford an interesting and instructive illustration of the principal phenomena.

Gyrostatic action, however, is a subject which lends itself essentially to purely mathematical treatment, the only principles assumed being the equations of rigid dynamics about whose validity no doubt exists at the present time. The case is entirely different with the properties of the screw propeller treated in Chapter V., and this fact is duly emphasised by Greenhill, whose introductory remarks should be very carefully studied. A complete mathematical theory would involve a study of the discontinuities at the edges of the propeller blades, a problem entirely beyond the methods of modern analysis, and which in all probability will remain unsolved for many generations, perhaps for

* Report on the Theory of a Stream Line past a Plane Barrier, and of the Discontinuity at the Edge, with the Application of the Theory to an Aeroplane. London: Wyman and Sons, Ltd. Price 5s.

ever. The treatment contained in this chapter forms a useful discussion of the various formulæ which have been proposed and the arguments on which they are based, but the fact must not be forgotten that certain assumptions are involved in all of these arguments.

The chief formulæ which are exact and not empirical are the relations between horse-power, angular velocity and propeller torque, between efficiency and slip, and between thrust, torque and pitch in a spiral screw working in a frictionless medium. Several of the older theories are based on the Newtonian hypothesis, as Greenhill himself has pointed out.

In connection with practical applications, attention should be called to the remarks on the rotational energy of the wake, and the methods of recovering this lost energy by a second screw of gaining pitch, placed behind the first, revolving the opposite way. This method we learn was tried in the early screw steamers, but it must not be forgotten that the problem of aviation involves working at far higher speeds than are required for large ships, so that an arrangement which was abandoned in one case may be very necessary in the other. Rotation of the wake can be decreased by decreasing the pitch, but this involves a corresponding increase in the rate of revolution, introducing difficulties well understood by practical men. On the other hand, if additional speed is gained by increasing the pitch, keeping the angular velocity constant, the angular momentum of the wake is increased, and unless twin screws are used the torque tending to heel the aeroplane over sideways is also correspondingly increased. It, therefore, seems likely that with the increasing size and speed of modern aeroplanes the arrangement in question may prove absolutely necessary, and that in adopting it, the loss of rotational energy, the disturbing torque of the propeller and the troubles arising from gyrostatic action may all be eliminated simultaneously. There seems no reason why the engines and propeliers of an aeroplane should not be mounted on one shaft perfectly free to revolve in its bearings independently of the aeroplane itself.

The last chapter deals with the pneumatical principles of an airship. So far as equilibrium is concerned the problem is one in elementary hydrostatics, the principles involved are therefore well known so that the main formulæ may be regarded as exact.

It is not to be denied that a man may become a successful aviator with nothing to guide him but his own practical experience, and knowledge based on the experience of his predecessors. On the other hand, the present volume should prove invaluable to every student of aeronautics who wishes to obtain an insight into the principles involved in the construction and working of flying machines.

G. H. BRYAN.

Essais d'Aerodynamique. Deuxième Série. Par A. de Gramont. Duc de Guiche. (Paris: Hachette. 1912. pp. 108, illus.)

THE present volume contains the results of a number of experiments carried out to vindicate the accuracy and to extend the range of a similar set of experiments which were described in the first volume of the series (reviewed in this Journal, July 1911, p. 130). The experiments traverse a well-worked ground being confined to the measurement of the pressure on rectangular planes, but the method employed is novel and interesting. The planes are attached to a framework which is carried on a racing motor car, and the pressures at different points are measured on a number of manometers whose readings are simultaneously photographed. In the first part of the present volume several objections which have been made against the method are dealt with. By a number of special experiments the author proved that the pressure on the plate is not affected by the disturbance caused by the body of the car and the supporting framework, and also that the pressure in the inside of the manometer box is unaffected by the forward motion of the car.

Coming now to the results, it is somewhat disheartening to find, after all the work that has been done in measuring the pressure on a square plane, that we are as far off from agreement as ever. The curve of resultant pressure which is found by adding up the manometer readings is totally different from the curve found by Eiffel for the same size of plane, the "hump" at 37° which figures prominently in the curves of Eiffel and the Göttingen experimenters being wholly absent.

The author attributes the difference between his results and those of Eiffel to some inherent difficulty in the way of applying the result of wind-channel experiments to the case of bodies moving forward in still air. We are unable to follow the reasoning by which he tries to show that while the theorem of relative motion may be applied to the case of a stream of air flowing in an unobstructed channel, it ceases to be applicable when an obstruction is placed therein. Apart from the influence of the sides of the channel, it seems to us that the two cases are kinematically identical provided the motion of the air stream is uniform, and that any discrepancy is capable of explanation as being due to the effect of the walls or to the sinuosity of the motion in the channel.

Another point of great importance raised is the influence of the dimensions of the plate on the distribution of pressure on the plate, and also on its total value. The pressure curves on a plate 80×80 cms. are very different from those on a 25×25 cms. plate, and the total pressure also shows a difference amounting in one instance to 15 per cent., this difference being in the opposite direction to that observed by other workers *i.e.*, a diminution of "k" with increase of size. The author makes out that this is due to the effect of the perimeter, that each side of the plane produces a band of perturbation whose breadth is constant and independent of the dimensions of the surface. The conclusion would violate the law of similarity and does not seem to be borne out by the experiments.

In conclusion we must pay a tribute to the industry and conscientiousness with which the elaborate series of experiments have been carried out, and hope that the author may be able to continue them and throw some light on the difficult problems which arise out of his results.

W. E. W.

Apprécier un Aéroplane. L'améliorer s'il y a lieu. By Capitaine du Génie Duchêne. (Paris: Librairie Aeronautique. 1912. pp. 58. Price 1 franc 50.)

"THE study and perfecting of any machine requires the solution of these two problems:—

"1. To apprize a given machine.
"2. To lay down the plan of a machine.

"We shall examine here the first of these problems as far as the aeroplane is concerned.

"The apprizement that we shall try to arrive at will be concerned exclusively with the mechanical qualities of the aeroplane, speeds of advance and ascent, power used, efficiency, &c., leaving out any consideration touching its equilibrium and the stability of its equilibrium."

Those familiar with Captain Duchêne's previous work will not need to be told to read the thesis he introduces in the above words, neither will it be necessary to inform them that it is thoroughly and capably written. Its appearance is most opportune at the present time, when the serious work of perfecting the aeroplane is being so widely discussed, and when we are in consequence asked to adopt diverse points of view as to what does and does not require to be considered when endeavouring to apprize a given machine.

Captain Duchêne takes us carefully through the salient points which we require to know, and shows by his usual clever use of graphs, how they are interrelated, and which are capable of alteration so that their ensemble, the complete machine, may be improved. It would be safe to hazard the opinion that few British designers could subject one of their machines to an "appréciation à la Duchêne" without finding some "lieu pour l'améliorer."

CORRESPONDENCE

To the Editor of the AËRONAUTICAL JOURNAL

THE LAWS OF AVANZINI

SIR,—In Col. de Villamil's interesting paper there are a few errors to which attention should be directed.

(1) Presumably the sign for the arithmetical difference of two quantities is a misprint for the ordinary sign for variation.

(2) On page 192, θ is (assuming correction 1) stated to vary as $1/f(V)$, while on page 204 θ is stated to vary as $f(1/V)$. Of course the form of the function f may be so chosen so as to express the result in either form that is preferred, but the two statements are not equivalent and once the choice has been decided on it is incorrect to substitute one form for the other, since it is generally not true that $1/f(V) = f(1/V)$. Thus to take a simple illustration, let

$$f(V) = aV + bV^2$$

then

$$\frac{1}{f(V)} = \frac{1}{aV + bV^2}$$

while

$$f\left(\frac{1}{V}\right) = \frac{a}{V} + \frac{b}{V^2}$$

(3) In the statements of the five laws the same symbol f is used to denote different functions. It might add very much to clearness of explanation if the different functions had been denoted by different symbols or distinguished by suffixes. Probably no misunderstanding will arise on this score.

(4) Assuming that readers of the paper have mentally or otherwise made the necessary corrections in these cases a more fundamental error occurs in the inference deduced at the problem of page 209. It is incorrect to infer *without further justification* that

$$\theta \text{ varies as } \frac{f_1(b)}{f_2(\rho) \times f_3(L) \times f_4(V)}$$

or that by a different choice of functions we may write θ varying as

$$f_1(b) \times F_2\left(\frac{1}{\rho}\right) \times F_3\left(\frac{1}{L}\right) \times F_4\left(\frac{1}{V}\right)$$

The correct inference may be written in the form

$$\theta = F\left(b, \frac{1}{\rho}, \frac{1}{L}, \frac{1}{V}\right)$$

and involves *a single function of four independent variables, not a product of four functions each of one independent variable.*

Of course it *may* happen in such a case that the function assumes the form given in the paper, but this does not follow from elementary algebra and the statement can only be justified if it is based on experimental evidence. The statement on page 206 that the relation between θ and $1/L$ "is most marked at high velocities" seems contradictory to any such assumption. If (keeping the other variables constant) we assume (as Col. de Villamil does) that

$$\theta \text{ varies as } F_3\left(\frac{1}{L}\right) \times F_4\left(\frac{1}{V}\right)$$

the law of variation of θ when L varies and V is constant will be independent of the velocity and will be the same at high as at low velocities.

In view of Col. de Villamil's statement that the laws obtained by Avanzini are to be regarded as qualitative rather than quantitative the particular form of the relation between the five variables stated on page 209 appears to be without justification.

G. H. BRYAN.

Plas Gwyn,
Bangor.

SIR,—Whilst thanking Professor Bryan for his criticisms, I would like to state, in mitigation of sentence, that I was abroad when the paper was printed and so was unable to read the proofs.*

(1) Correct: This appears fairly evident from the context.

(2) Error on page 204:

$$f\left(\frac{1}{V}\right) \quad \text{should be} \quad \frac{1}{f(V)}.$$

I have not my manuscript so do not know if this is my fault or that of the printer.

(3) I am inclined to agree with this: as, however, we know next to nothing about the form these functions take, no misunderstanding is likely to arise from the omission of suffixes.

(4) I suppose I must cry *peccavi* for the "sign of multiplication": a comma, in place of this, would have expressed the meaning I intended to convey. Professor Bryan's

$$= F\left(b, \frac{1}{\rho}, \frac{1}{L}, \frac{1}{V}\right)$$

would appear even more elegant.

Page 206: This phrase is badly worded and the objection is quite sound. What I meant was that the *effect* was more *apparent*, or *noticeable*, at high velocities.

I regret that a few other errors have crept in.

Page 194, line 7: "Lights" should be "Sights" (see the "eyes" on Plate II.).

Page 197. Expt. IV.: Angle 8° 30′ should be 18° 30′.

Page 199. Expt. IV.: Angle 28° 38′ should be 20° 38′.

Page 201. Expt. I. (in Air): Angle 15° 33′ should be 15° 33″. (As Avanzini was not able to measure to seconds, this may be either (1) an error in the original or (2) the mean of a large number of experiments.)

Page 202. Expt. IV.: Angle 9° 30′ should be 9° 30″. (Same remarks.)

It may be interesting to know that Colonel Duchemin (*Les lois de la résistance des fluides*), in referring to Avanzini's work on page 224 of his book falls into an error:—

"4° En faisant varier les dimensions de la plaque, sans changer ni la vitesse ni l'intervalle *ce*, on observe qu'avec *l'augmentation de la longueur ab* l'angle *bcd* devient *moins aigu*." This is obviously an oversight, for he concludes the paragraph, "D'ou l'on conclut que le centre de résistance s'approche d'autant plus *du centre de figure* que la plaque *est plus longue*."

R. DE VILLAMIL.

MILITARY AERONAUTICS.

September, 1912.

SIR,—Having read with very great interest in the July number of the JOURNAL the lecture given by Brigadier-General D. Henderson, C.B., D.S.O., on "The Design of the Military Scouting Aeroplane," also the very interesting discussion which ensued, I cannot resist the temptation to offer a few remarks in the hope that they may be of service.

While all due weight must be given to lessons derived from military experience in the past, I think that much additional help may be derived from careful observation of those who are accustomed to go about their business at high speeds, viz.:—the birds and fishes. For instance, the question of invisibility has been settled, as a rule with very few exceptions, for those birds and fishes that live on or close under the surface of the sea and are liable to attack both from above and below. They require to be as inconspicuous as possible and their undersurfaces are *pure snow-white*, while the upper surface is a darkish brown or gray. The reason for this arrangement of colour is obvious.

Then again in fighting tactics something may be learnt from the crows. When they get a "wireless" they proceed to the spot indicated each "on his own" and when they have completed their task, or if they are attacked meanwhile they *disperse* and return.

* It should be said that the proofs of his paper were read for Col. de Villamil by a gentleman selected by him.—EDITOR.

No longer will a general march sword-in-hand at the head of his serried ranks. He will sit in his office and the weather being suitable, perhaps an hour before dawn, he will send out a wireless to his men something like this:—"At 7.10 a.m. (say 10 minutes after daybreak) you must arrive at No. .. locality (on map of enemy's country, it may be 50 miles beyond the frontier) and participate in destruction of ..... railway station. Then disperse, return and report." When the aviator arrives at his destination he finds that he is only one of a hundred approaching from different directions who have all come on the same errand.

ALAN OWSTON.

Yokohama.

SOARING FLIGHT

SIR,—Referring to Dr. Hankin's paper on "The Soaring Flight of Birds" in the April number of the JOURNAL, I would like to put forward a theory, for whatever it may be worth only, as it is not supported by any exact experiments.

One very hot summer day I was walking along a shingly beach very greatly oppressed by the heat. I took refuge in a tea-house, standing back maybe a hundred yards from the sea. From the upper verandah of this tea-house a bamboo sun-shade extended for some fifteen or twenty feet, and to my great surprise and relief I found there was a marvellous cool breeze blowing in. On the sea there was just a light air but when this reached the shore it was driven straight up by the currents rising from the heated shingle. The phenomenon is of course common enough, but this instance was so marked as to create a lasting impression. It was like extracting a cool breeze from a furnace. Now, may not the cooling of the air in the shade beneath the outspread bird cause a draught of wind to blow after it? This would certainly agree with Dr. Hankin's statement (page 84) that "the air under the wing is more compressed than the air over the wings." The effect of such a draught might possibly be cumulative up to a certain point and it seems to be generally admitted that very little force is required to propel the bird. In the case cited above it is easy to conceive that if the tea-house had been mounted on wheels it might have been moved by the wind induced by itself. The conditions appear to be generally the same as those required for the formation of a waterspout, only on a miniature scale; viz.: a column of dense shade. It may be noted that soaring birds are generally well provided with shade feathers, viz.: large thick secondaries, and I have noticed the very sharply-defined shadow birds throw on the ground when soaring.

Sailing-flight I take to be quite a different affair from sun-soaring, although at times the two may be used in combination. Birds equipped specially for sailing flight such as the albatross and gannet are poorly provided with secondaries.

If one might do a little soaring oneself into the realms of speculation, might it not be possible that the vulture soaring at great height is assisted in finding his food in calm weather by a column of air blowing directly to him from a definite spot, or line on the ground?

To sum up—the theory I suggest is that the power required to support and propel a bird when soaring is derived from the difference between the temperature in the direct rays of the sun and in the shadow of the bird. The exact working of the principle is doubtless well-known to designers of hot-air engines.

ALAN OWSTON.

Yokohama.

A.B.C. OF HYDRODYNAMICS

SIR,—Your reviewer complains that I made no mention of Bernouilli in my book; I certainly thought it superfluous and quite unnecessary.

Your reviewer's reference to him is, moreover, inaccurate. Bernouilli was not an Italian, and he did not publish his book in Italian. He was a Swiss and a Professor at Bâle. His *Hydrodinamica* is published in Latin.

Venturi was an Italian, but his *Recherches Expérimentales* was published in Paris and in French. The date (1860) given by your reviewer is not correct; a reference to the title page where the author is called "le Citoyen J. B. Venturi" would make one suspect that the date was about that of the Battle of Marengo, or earlier—the exact date was year VI. (1797).

An English translation was published in London in 1799.

R. DE VILLAMIL.

OBITUARY

CHARLES VOISIN

CHARLES VOISIN succumbed on September 26th to injuries sustained in a motor-car accident near Macon, and with him disappears one of the small and sadly-dwindling band of pioneers who, some six years ago, laid the first stone on which French aerial supremacy has since been raised. Overshadowed to some extent by the more brilliant technical and executive abilities of his brother Gabriel, Charles Voisin nevertheless played an important part in those early moving days of the history of aviation.

Born at Lyon on July 12th, 1884, Charles Voisin, after completing his military service, joined his brother Gabriel in 1906 to found, with the support of M. Ernest Archdeacon, the firm of Voisin Frères, the first aeroplane constructors in the world. After conducting a number of gliding experiments the Voisins resolved to build a motor-driven aeroplane, and, though the only data they possessed were those derived from their own experiments, resolved upon the bold step—remember that but one machine had before then succeeded in making a public flight—of offering a guarantee of flight to the purchaser of their aeroplane. The purchaser, Léon Delagrange, was soon found, and on March 30th, 1907, Charles Voisin made his first flight on the lawns of Bagatelle. The subsequent history of this, the first aeroplane ever built for any but experimental purposes, is well known. It stands to the everlasting credit of Charles Voisin that he collaborated to found the industry of aviation.

Early this year he severed his connection with the firm he had helped to establish, and proceeded to South America to organise the highly successful tour made by Garros, Barrier, and Audemars. Death overtook him shortly after his return, in the midst of his activities, cutting short a career which is not only inseparably bound up with the commencement of aviation, but was fraught with every promise of a useful and active future

J. H. L.